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Tech Notes

OCTOBER 1991

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Technology fact sheets from Federal laboratories

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

October 1991

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Published monthly by the National Technical Information Service (NTIS), Tech Notes bring together individual one- to two-page fact sheets prepared by Federal agencies, their laboratories, or contractors. These fact sheets highlight current Federal technology determined to have commercial or practical application. Topics cover new processes, materials, techniques, software, instrumentation, and resources.

Some of the current sources are the Department of the Navy, Department of the Army, NASA, Department of Energy, Environmental Protection Agency, Department of the Interior, and the Department of Agriculture.

Special assistance is provided by the Federal Laboratory Consortium.

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Every Tech Notes fact sheet lists a source for additional information. The source of this information may be a special support package from the originating agency, a personal contact, a licensing opportunity, or a backup report available from NTIS.

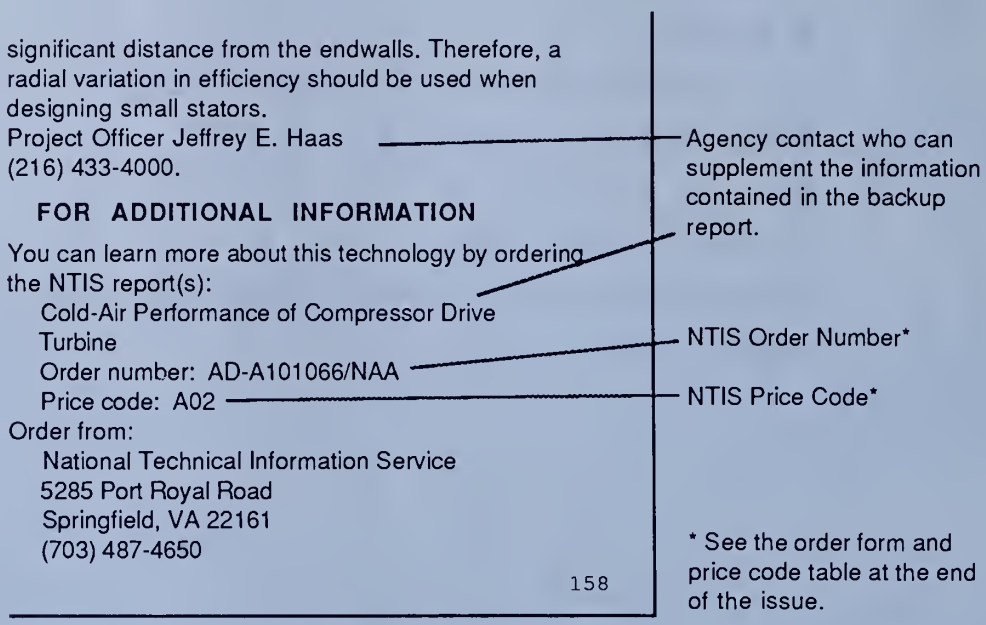
Each fact sheet also is perforated to allow for easy removal for those subscribers who may wish to keep a special fact sheet file or route to others in their organization

Sources of Further Backup Information

Below are two representative examples of how each Tech Note fact sheet provides you with a source of further information. In most cases, this information is provided directly by the agency or its laboratory.

However, there are cases where NTIS is the source for backup documentation. In these cases, use the order form at the end.

Examples:


significant distance from the endwalls. Therefore, a radial variation in efficiency should be used when designing small stators.
Project Officer Jeffrey E. Haas
(216) 433-4000.
FOR ADDITIONAL INFORMATION
You can learn more about this technology by ordering the NTIS report(s):
Cold-Air Performance of Compressor Drive Turbine
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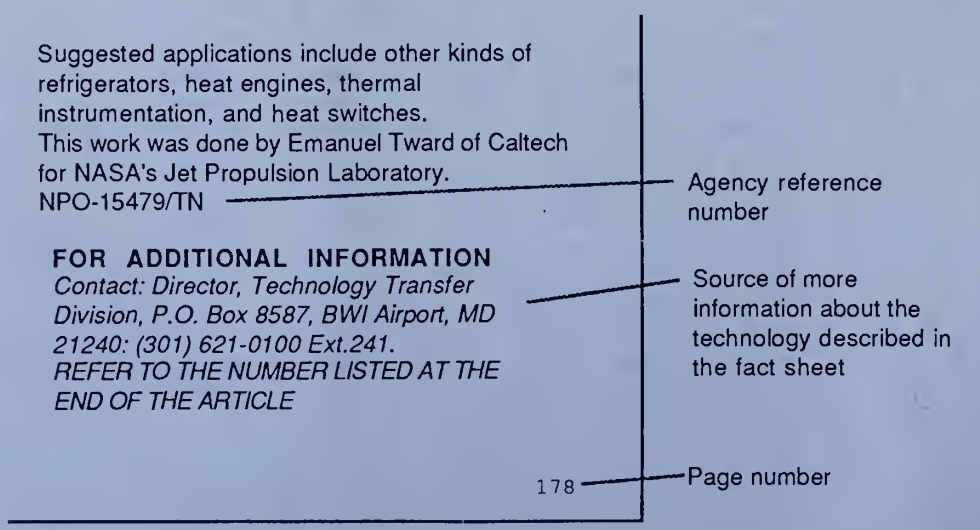
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN
FOR ADDITIONAL INFORMATION
Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE
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Testing & Instrumentation

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Testing & Instrumentation

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Natural Resources Technology & Engineering

0827 Abandoned Mine Lands Program TN#1 Subsidence Abatement Investigation Laboratory (SAIL)

Other Items of Interest

0803 Highly Accurate Sensor for Soils

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0829 Navy Invents Protective Communications Helmet (Licensing Opportunity)

Testing & Instrumentation

0830 GC/MS Gas Separator Operates at Lower Temperatures—Less power is consumed, and the catalytic hydrogenation of compounds being analyzed should be diminished.

0831 Measuring Flux Density of Monatomic Oxygen—Two probes measure heat of recombination on a catalytic surface. (Licensing Opportunity)

Other Items of Interest

0782 Compact X-Ray and Extreme-Ultraviolet Monochromator—This low-cost monochromator can operate at selected wavelengths in a wide spectral range. (Licensing Opportunity)

0804 Sensing Chemicals

0815 The Monomer of Your Choice Can Now be Modified—Enzymes Add Carbohydrates for Synthesis of Biocompatible Polymers (Licensing Opportunity)

Agriculture & Food

0772 Broken Rice Tied to Nitrogen

Software

0773 RANGETEK, a Rancher's Best Friend

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Broken Rice Tied to Nitrogen

Neatness counts—especially when it comes to rice farming.

That's the news from plant geneticist Robert H. Dilday at ARS' Rice Production and Weed Control Research Unit at Stuttgart, Arkansas. Dilday says the results of a 3-year study show that hit-or-miss application of nitrogen fertilizer on rice can land farmers a failing grade where it hurts the most—in payments at the mill.

"With varieties of rice that take a lot of nitrogen fertilizer such as the semidwarfs, we saw twice as many broken kernels—called brokens—when the rice wasn't fertilized," Dilday notes. "Rice millers pay only half as much for rice that contains a lot of brokens.

"This means that when you aerially apply your nitrogen, you have to be sure you get an even distribution and don't miss strips in the field. If you do miss strips, you could be shooting yourself in the foot twice: once in lost production, and again in lower prices paid for the rice at the mill."

In Dilday's experiments, nitrogen was applied to test plots of Lemont and Newbonnet rice in several ways: all the nitrogen at once, before flooding of the rice field; half at preflood and the rest in two equal doses later in the growing season; and a six-way split. Other plots received no nitrogen at all.

In 1987, Lemont rice that received all its nitrogen fertilizer preflood had only 14.2 percent brokens, Dilday recalls. That same year, his Lemont rice that received no fertilizer had 33.3 percent brokens.

Lemont is one of the semidwarf varieties favored by farmers. Among the attributes of semidwarf varieties is a resistance to lodging—a condition where the rice stalk breaks, dumping the head onto the ground.

But rice doesn't have to be a semidwarf variety to show the harmful effects of sloppy nitrogen application. Newbonnet also suffered from the absence of nitrogen in Dilday's tests, although percentages of brokens weren't as great: 15.6 percent brokens in 1987 with no nitrogen, compared with 11.9 percent brokens when all the nitrogen was applied preflood.

Nor is nitrogen application the only pitfall awaiting rice producers. Dilday says other studies at Stuttgart have shown that poor timing of field drainage before harvest can hurt rice quality, too.

"A lot of times, farmers like to drain the field early because if they leave the water on too long, they have a really muddy field and a devil of a time moving around with their harvest equipment," Dilday explains.

"We've tried draining at different times and actually harvesting the rice with the water still on the field. Our studies show the longer you leave the water on the field, the lower your percentage of brokens."

Robert H. Dilday is in USDA-ARS Rice Production and Weed Control Research Unit, P.O. Box 287, Stuttgart, AR 72160. Phone (501) 673-2661. ◆

RANGETEK, a Rancher's Best Friend

Protecting rangelands from overgrazing by cattle may become easier, thanks to a new computer program called RANGETEK. The user-friendly program helps ranchers determine the optimum number of cattle to graze on a specific range.

Many factors influence range stocking rates. For instance, the types and amounts of forage grasses, like bluebunch wheatgrass or Idaho fescue, affect the rate, as does how much it rained before the growing season, says J. Ross Wight, one of the program's designers. Wight, a range scientist, works at the ARS Watershed Management Research Unit in Boise, Idaho.

"Based on past weather records, the program can tell you how much forage will likely be available during the upcoming season in a specific region. That information helps determine the number of cattle that can safely graze there," says Wight.

Grazing too few cattle when there's plenty of forage cuts into a rancher's income, but grazing too many, too long, can wipe out the best forage species. Overgrazed land is also more susceptible to erosion, he adds.

RANGETEK prompts users for information about soil type, the predominant plant species, and the length of the growing season on the range in question—information all resource managers have. Armed with long-term weather records available from weather stations, along with the soil moisture status at the beginning of the growing season, the program can forecast the likelihood of having a good, bad, or average year, in terms of plant growth.

Soil moisture and weather data files are currently being developed for range sites in Idaho, specifically for RANGETEK. However, the program can be used wherever the data can be measured.

Another option is entering actual values for temperature and rainfall every week during the season, which gives a real-time simulation of soil water content as plants grow. The resource manager could then keep tabs on the current range conditions, without having to actually measure the soil moisture content.

The program would give resource managers enough advance information so that they could move cattle from a pasture in time to prevent damage due to overgrazing.

The Department of Interior's Bureau of Land Management and the USDA's Forest Service, which controls most of the publicly owned land suitable for grazing, will likely find the new technology beneficial, says Wight.

This spring, Wight, along with scientists from USDA's Soil Conservation Service and state extension personnel, will use RANGETEK to forecast forage yields in key range sites across Idaho. The results should help refine the program's accuracy and provide detailed information on the impact of a potential drought in Idaho's rangelands.

J. Ross Wight is with the USDA-ARS Watershed Management Research Unit, N.W. Watershed Research Center, 800 Park Blvd., Plaza IV, Suite 105, Boise, ID 83712. Phone (208) 334-1363. ◆

Computers

0774 Information Systems Dictionary Adopted as FIPS

Software

0775 Generating Three-Dimensional Grids About Anything—A Poisson's-equation scheme can fit a grid to a body of arbitrary shape.

0776 Systematic Identification of Discrepant Hardware—The material-review process is automated for greater speed and efficiency.

NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Information Systems Dictionary Adopted as FIPS

The American National Dictionary for Information Systems (ANSI X3.172-1990) has been adopted as a FIPS (Federal Information Processing Standard) Guideline. The dictionary consists of an alphabetic listing of terms and their definitions. The FIPS provides a reference within the federal government for terms and definitions used in such fields of information systems as computers, data communications, and data processing.

FOR ADDITIONAL INFORMATION: The publication is available from the National Technical Information Service, Springfield, VA 22161; (703)487-4600. Order by FIPSPUB11-3 for $45 prepaid.

NASA Tech Brief
National Aeronautics and Space Administration

Computer Software

Generating Three-Dimensional Grids About Anything

A Poisson's-equation scheme can fit a grid to a body of arbitrary shape.

The ability to treat boundaries that have arbitrary shapes is one of the most desirable characteristics of a method for generating grids. The Three-Dimensional Grids About Anything by Poisson's Equation (3DGRAPE) computer program is designed to make computational grids in or about almost any shape. These grids are generated by the solution of Poisson's differential equations in three dimensions. The program automatically finds its own values for inhomogeneous terms that give near-orthogonality and controlled grid-cell height at boundaries. Grids generated by 3DGRAPE have been applied to both viscous and inviscid aerodynamic problems, and to problems in other areas of fluid dynamics.

3DGRAPE uses zones to solve the problem of warping one cube into the physical domain in problems of computational fluid dynamics. In a zonal approach, a physical domain is divided into regions, each of which maps into its own computational cube. It is believed that even the most complicated physical region can be divided into zones, and since it is possible to warp a cube into each zone, a grid generator that is oriented to zones and provides communication across zonal boundaries (where appropriate) solves the problem of topological complexity.

3DGRAPE accepts input in the form of already-distributed x, y, z coordinates on the bodies of interest — coordinates that remain fixed during the entire grid-generation process. The 3DGRAPE code makes no attempt to fit given body shapes and redistribute points thereon. Body fitting is a formidable problem in itself. The user must either be working with a body of some simple analytical shape, upon which a simple analytical distribution can be easily effected, or must have available some sophisticated stand-alone body-fitting software.

3DGRAPE does not require the user to supply the block-to-block boundary surfaces or the distribution of points on them. 3DGRAPE typically supplies those block-to-block boundaries simply as surfaces in the elliptic grid. Thus, at block-to-block boundaries the following conditions are obtained: (1) grid lines match up as they approach the block-to-block boundary from either side, (2) grid lines cross the boundary with no discontinuity in slope, (3) the spacing of points along a line piercing the boundary is continuous, (4) the shape of the boundary is consistent with the surrounding grid, and (5) the distribution of points on the boundary is reasonable in view of the surrounding grid.

3DGRAPE offers a powerful building-block approach to the generation of complicated three-dimensional grids, but it is a low-level software tool. Users can build each face of each block as they wish, from a wide variety of resources. 3DGRAPE uses point-successive-over-relaxation (point-SOR) to solve the Poisson equations. This method requires a large number of iterations, but it vectorizes nicely. Any number of sophisticated graphics programs can be used on the stored output file of 3DGRAPE even though it lacks interactive graphics. Versatility was a prominent consideration in developing the code. The block structure allows a great latitude in the problems it can treat. As the full title of 3DGRAPE implies, this program should be able to handle just about any physical region into which a computational cube or cubes can be warped.

3DGRAPE was written in 100 percent FORTRAN 77 and should be machine-independent. It was originally developed on a Cray computer under COS and tested on an IRIS 2500T workstation under UNIX.

This program was written by Reese L. Sorenson of **Ames Research Center**.
ARC-12620/TN

FOR ADDITIONAL INFORMATION

CONTACT

COSMIC®
112 Barrow Hall
University of Georgia
Athens, GA 30602

(404) 542-3265

NASA Tech Brief
National Aeronautics and Space Administration

Systematic Identification of Discrepant Hardware

The material-review process is automated for greater speed and efficiency.

The basic function of a manufacturer's production-support-engineering unit is to identify, document, and dispose of hardware that does not conform to drawing requirements. CAMRAD, a program designed for rapid input and retrieval of all data used in engineering-to-manufacturing support operations, aids the engineer by automating the material-review-disposition process. Before CAMRAD, material-review record searches were manual. The time spent searching through old documents precluded the timely disposition of new material reviews. CAMRAD facilitates the research of material-review histories and provides for the efficient processing of material-review documents.

Three SmartWare project files control the operation of CAMRAD. The project file CAMRAD initializes variables for the other project files and specifies the paths of the CAMRAD program, data-base files, and document files. The project file DATARAD controls all data-management functions. The data base consists of individual files that contain all records of specific hardware discrepancies for a part designated by a given number.

There are four basic avenues for a search of records: the serial number of a part, a feature of the part, the Material Review (MR) number, and nonconformance. WORDRAD is the project file that controls the management of document files created when processing a material-review disposition. Given a material-review report that identifies a defective item of hardware, the production-support engineer can use CAMRAD to search the data base quickly for any history of the same problem, find out how well the problem has been documented, and create appropriate documentation for this latest occurrence.

CAMRAD is written in the Smart programming language and is designed to run on IBM PC compatibles with the SmartWare version 3.1 software package available from Informix Software. CAMRAD was developed in 1987.

SmartWare is a registered trademark of Informix Software, Inc. IBM PC is a registered trademark of International Business Machines Corporation.

This program was written by Timothy L. Hannah and William R. Stinson of Caltech for **Marshall Space Flight Center.** *MFS-29525/TN*

FOR ADDITIONAL INFORMATION

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112 Barrow Hall
University of Georgia
Athens, GA 30602

(404) 542-3265

Electrotechnology

0777 Inconspicuous Antenna System Employing the Airframe as an Antenna (Licensing Opportunity)

0778 Multilevel Mate Pair Code Compressor for Codes Expanded by the Process of Butting (Licensing Opportunity)

0779 Tactical High Frequency Array Antennas (Licensing Opportunity)

0780 Acousto-optical Filter Can Rapidly Tune Solid-State Lasers—Output wavelength can be randomly selected in microseconds.

0781 Burst-Compression and -Expansion for TDMA Communication—Variable-data-rate users are interconnected via a satellite-switched network.

0782 Compact X-Ray and Extreme-Ultraviolet Monochromator—This low-cost monochromator can operate at selected wavelengths in a wide spectral range. (Licensing Opportunity)

0783 Diplex Fiber-Optic Link for Frequency and Time Signals—Relatively inexpensive equipment delivers signals of high quality.

0784 Flange Correction for Metal-to-Metal Contacts—Interfacial resistances can be extracted more accurately from four-terminal Measurements.

0785 Multiple-Symbol Detection of Multiple-Trellis-Coded MDPSK—An increase in the observation time would reduce the probability of error.

0786 Self-Injection Locking of Diode Lasers—Several modes are locked to a single spatial mode and frequency. (Licensing Opportunity)

Testing & Instrumentation

0787 High Speed, Low Noise ASIC Preamplifier

0788 Airborne Calibration of an Orbiting Radiometer—Measurements enable compensation for degradation of optics and changes in detector circuitry.

Other Items of Interest

0797 Electromagnetic Gun With Commutated Coils—Greater speeds should be attainable.

0829 Navy Invents Protective Communications Helmet (Licensing Opportunity)

U.S. Army Fact Sheet

Licensing Opportunity

Army Communications-Electronics Command

Inconspicuous Antenna System Employing the Airframe as an Antenna

It is an object of the present invention to provide an improved phase homing system antenna wherein the antenna elements are concealed or greatly reduced in profile. In accordance with the present invention, there is provided a phase front homing system airplane antenna comprising two substantially vertical sections of the airframe of the airplane. Included are discrete coaxial coupling sleeves, identical in structure, which encompass a portion of each of the vertical airframe sections such that the combination of each of the coupling means and its associated vertical section comprise one element of a pair of antennas of the system. Also included is a radio frequency feed line at each of the antenna elements which is connected between a respective coaxial sleeve and its associated vertical section. The phase front homing system derives the desired sense of direction to a prescribed beacon transmitter by utilizing directly the phase difference of the voltage at the two antenna elements.

STATE OF DEVELOPMENT

The method has been laboratory proven and tested for use by the United States Army.

APPLICATIONS

The invention can be directly applied to aircraft wherein a homing signal is required to fulfill the mission of the craft. It however must be understood that although the primary application is one of a homing nature, the invention may also be used as a communication antenna.

PATENT STATUS

U.S. Patent Number 4,117,490

FOR ADDITIONAL INFORMATION: Charles Grzenda, Chief, Office of Research and Technology Applications, Center for C3 Systems, ATTN: AMSEL-RD-C3-SD, Fort Monmouth, NJ 07703; Telephone (908)544-3119. Refer to application assessment number 011.

U.S. Army Fact Sheet

Licensing Opportunity

Army Communications–Electronics Command

Multilevel Mate Pair Code Compressor for Codes Expanded by the Process of Butting

The object of this invention is to provide a spread spectrum perfect noise code class that compresses to a lobeless impulse which can be easily implemented at low cost and whose quantity is virtually inexhaustible for practical time-bandwidth products or code lengths "n". Multiplexed noise codes as a class has far reaching implications and value for numerous practical applications. Systems using these codes are extremely resistant to interception and interference, operate with no self-interference, eliminate the near/far ratio problem, operate with optimum resolution for range and velocity, can readily employ optimum RAKE diversity to counter multipath returns, provides reliable transmission and have an inexhaustible supply of orthogonal noise code sets from which to choose.

STATE OF DEVELOPMENT

The method has been theoretically verified and demonstrated by laboratory experiment.

APPLICATIONS

Potential uses are for improved telecommunications, local area networks, personal communication networks, mobile and multiple access systems, inter-communication systems, secure transmission, switching systems, radar, air traffic control, navigation systems, electron microscopes, remote control systems and personal burglar alarm systems.

PATENT STATUS

U.S. Patent Number 4,542,515

FOR ADDITIONAL INFORMATION: Charles Grzenda, Chief, Office of Research and Technology Applications, Center for C3 Systems, ATTN: AMSEL-RD-C3-SD, Fort Monmouth, NJ 07703; Telephone (908)544-3119. Refer to application assessment number 015.

U.S. Army Fact Sheet

Licensing Opportunity

Army Communications-Electronics Command

Tactical High Frequency Array Antennas

It is the object of this invention to provide a high performance, light weight portable antenna which provides unidirectional radiation and reception of high frequency radio waves at low take off angles above the horizon in a compact configuration and which is particularly adapted for field use and can operate to provide communications in the High Frequency Band (2-30 MHz) of the electromagnetic spectrum over medium range and long range ionospheric circuits. The invention provides an antenna which exhibits high front-to-back ratio, increased directivity gain, and a low angle of radiation in a single direction which eliminates the need for an elaborate ground system or an impedance matching network.

STATE OF DEVELOPMENT

The method has been laboratory proven and tested for use by the United States Army.

APPLICATIONS

The invention can be directly applied to all high frequency communication systems and in particular, to those which have a restoration of communications application. In addition, all systems that operate over the HF frequency range and have field applications would benefit from the addition of this antenna array.

PATENT STATUS

U.S. Patent Number 4,611,214

FOR ADDITIONAL INFORMATION: Charles Grzenda, Chief, Office of Research and Technology Applications, Center for C3 Systems, ATTN: AMSEL-RD-C3-SD, Fort Monmouth, NJ 07703; Telephone (908)544-3119. Refer to application assessment number 013.

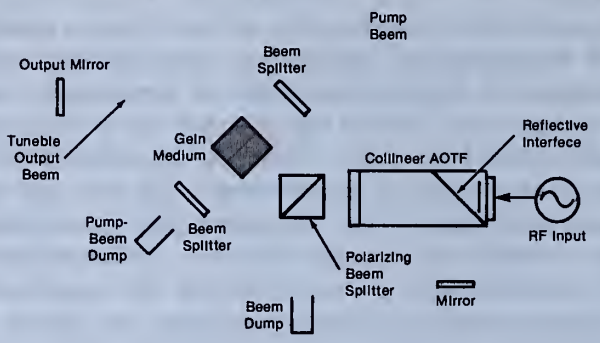
NASA Tech Brief
National Aeronautics and
Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Acousto-optical Filter Can Rapidly Tune Solid-State Lasers

Output wavelength can be randomly selected in microseconds.

The incorporation of an acousto-optical tunable filter (AOTF) in the cavity of a solid-state laser, such as a Ti:Sapphire laser, would provide a means of adjusting the wavelength of the laser output electronically, according to a recent proposal. The table shows the tuning range of several solid-state lasers with particularly broad tuning ranges. Incorporation of this technique with up/down conversion could be used to extend this range even further.

Typically, the AOTF is placed inside the laser cavity and is driven with a sinusoidal RF signal (see figure). The frequency of the RF signal determines the center of the spectral bandpass of the AOTF and hence the wavelength of the laser output. The laser can be programmed to produce multiple output wavelengths simultaneously by driving the AOTF with several RF frequencies. Pulsing an intercavity AOTF periodically could provide a means for wavelength-selectable mode-locking.



The **Intercavity Acousto-optical Tunable Filter** provides a method of rapidly tuning a solid-state laser to any wavelength within its gain profile.

Since the AOTF can be tuned in as little as 1 μs with a resolution as small as 1 Å, this technique could be useful in remote-sensing applications, such as in a differential-absorption lidar (DIAL) and in communications for wavelength-division multiplexing.

This work was done by James L. Lambert of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17891/TN*

Laser	Tuning Range
$Ti:Al_2O_3$	690-1,050 nm
NaCl:OH	1,420-1,850 nm
Co:MgFl	1,750-2,500 nm

Tuning Ranges for wide band solid-state lasers.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and
Space Administration
Lewis Research Center, Cleveland, Ohio

Burst-Compression and -Expansion for TDMA Communication

Variable-data-rate users are interconnected via a satellite-switched network.

A burst-compression and -expansion technique enables the interconnection of users transmitting and receiving data at rates asynchronous with respect to clocks within the ground terminals of a satellite-switched, time-division-multiple-access (TDMA) communication network. In such a network, a matrix switch aboard the satellite routes bursts of data from source users received on uplink antennas to downlink antennas that illuminate ground areas containing destination users. Each burst is timed so that while it lasts, only one pair of source and destination users is communicating; and during the burst, the full receiving, switching, and transmitting resources of the satellite are allocated to that pair. These resources are divided or time-division-multiplexed among all active users in the network. Greater flexibility in interconnecting widely dispersed users is achieved by use of hopping beams. Multiple uplink and downlink antenna beams are electronically switched to cover specific source and destination locations simultaneously in a periodic sequence. Source and destination users in covered locations communicate with each other through TDMA ground terminals (see Figure 1).

At each source terminal, lower-rate, continuous digital data streams from multiple users are compressed into high-rate bursts for modulation and transmission in the assigned time slots within the TDMA frame (see Figure 2). Serial data from each source user are temporarily converted to a parallel format and stored in one of several compression buffers. At the assigned time, parallel data are read out of the compression buffer onto the multiplexed-data bus, scrambled, converted to a high-rate, serial data format, modulated, and transmitted as a burst. Bursts received by the destination terminal are demodulated, converted back to a parallel format, descrambled, and expanded back into continuous data streams at the original lower data rates and delivered to the destination users.

To support multiple users with a wide range of asynchronous data rates, the number of bits of user data transmitted by the source terminal from frame to frame must vary. At the destination terminal, the regenerated bit clock delivered to the user must replicate the frequency and stability of the source user. The key feature of the technique is to group the number of lower-rate user data bits received by the source terminal over roughly one frame period into an equivalent number of higher-bit-rate valid data words each frame and thereby "quantize" the frame-to-frame variation in the number of valid data bits per frame into one-word increments. This grouping of user data into words is performed by the compression buffer; continuous user data are written into the first-in, first-out (FIFO) memory at the user's clock rate and are read out at the burst modulator clock rate. Each transmitted burst is an integer number of words in duration. On a frame-to-frame basis, the number of valid words in the burst may increase or decrease by one from some nominal number that represents the approximate data throughput.

In the destination terminal, a control loop subroutine executing in the user interface controller varies the frequency of a voltage-controlled oscillator (VCO). The VCO is used to generate both the read clock for the expansion buffer and the data synchronized bit clock delivered to the destination user. The control loop adjusts the regenerated clock frequency based on the fill level of the expansion buffer observed at the end of each frame.

Through the use of nominal and valid data-word counts, FIFO memories, adjustments to the duration of transmit and receive frames, and microprocessor-controlled regeneration of clock signals, the variable-rate-compression-and-expansion-buffer technique preserves bit integrity and minimizes overhead and latency for low-to-medium-data-rate users who are not traditionally served by TDMA networks. The technique enables the use of inexpensive clock sources by both the users and the ground terminals and obviates the need for elaborate user-clock-synchronization processes. The technique accommodates a continuous range of data rates from kilobits per second to that approaching the modulator burst rate (hundreds of megabits per second).

This technique was developed for use in NASA Lewis Research Center's satellite network simulation facility. Some key features of the technique have also been implemented in the ground terminals developed at NASA Lewis for use in on-orbit evaluation of the Advanced Communications Technology Satellite high-burst-rate system.

This work was done by James M. Budinger of **Lewis Research Center.** *Further information may be found in NASA TM-102414 [N90-15983], "A Burst Compression and Expansion Technique for Variable-Rate Users in Satellite-Switched TDMA Networks."*

Copies maybe purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Ruch orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15102/TN

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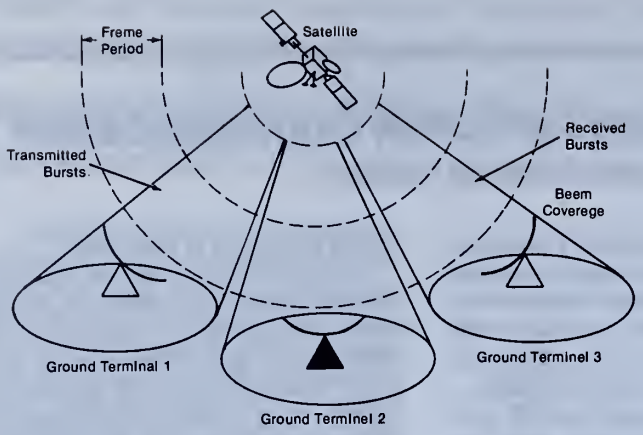

Figure 1. In a **Multiple-Beam, Satellite-Switched TDMA Network**, multiple pairs of source and destination users take turns communicating via a satellite and ground terminals.

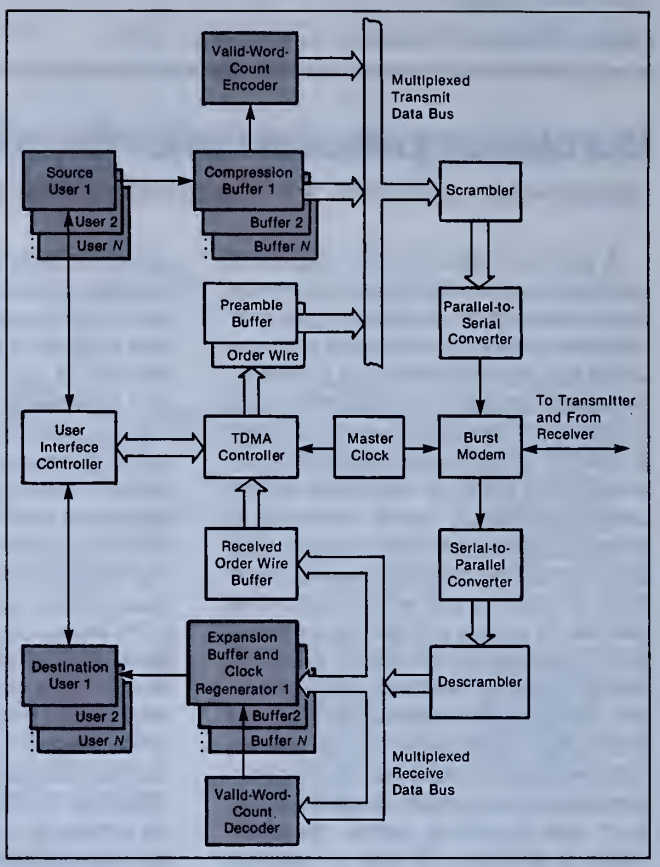

Figure 2. A **TDMA Ground Terminal** compresses streams of data from source users into rapid bursts for transmission and reexpands bursts of received data into slower streams of data for delivery to destination users.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Compact X-Ray and Extreme-Ultraviolet Monochromator

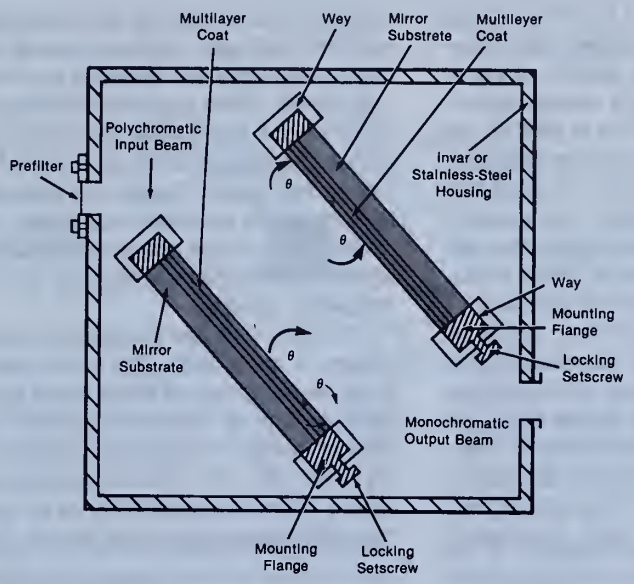
This low-cost monochromator can operate at selected wavelengths in a wide spectral range.

A monochromator for x-ray and extreme-ultraviolet radiation provides higher spectral resolution than can be achieved with thin-metal-foil broad-band-pass filters. It operates over a much broader x-ray and extreme-ultraviolet spectrum than devices based upon natural crystals do, and in comparison with a typical grating monochromator, it is smaller and less expensive. The new monochromator is intended to filter the continuum radiation from sources like synchrotrons, laser plasma sources, free-electron lasers, and wigglers to produce monochromatic beams for testing and analysis of x-ray and extreme-ultraviolet telescopes and microscopes, for calibration of photographic films and detectors, for biological and biomedical research, for x-ray lithography, for processing of materials, and for research in the properties of materials.

As shown schematically in the figure, the monochromator includes a pair of mirror substrates with identical reflecting multilayer coats. These mirrors are mounted in a housing of stainless steel or low-thermal-expansion alloy on surfaces machined and lapped precisely to keep the mirrors parallel to each other. The radiation enters the monochromator housing through a prefilter that filters out visible and longer-wavelength ultraviolet light.

The mirror substrates — made of sapphire or low-thermal-expansion glass/ceramic composite — must be superpolished to a roughness of less than 3 Å root mean square. The reflecting coat on each substrate consists of many alternating layers of high-atomic-number x-ray-diffracting material separated by layers of low-atomic-number spacing material. All layers are uniform and of accurately repeatable thicknesses throughout the multilayer stack.

Each multilayer coat constitutes a synthetic Bragg crystal, which reflects x rays by Bragg diffraction. The wavelength at which the peak of the reflected flux occurs is given by the Bragg relation $N\lambda = 2D \sin\theta$, where N is the order of the diffraction (usually 1); D is the effective thickness of a high-atomic-number/low-atomic-number pair of layers, corrected for the effect of refraction; and θ is the angle between the incident beam of radiation and the surface of the mirror. The reflection from both mirrors occurs at angle θ, and the reflection from the second mirror narrows the spectrum that remains after the reflection from the first mirror.



The **Compact Multilayer X-Ray and Extreme-Ultraviolet Monochromator** uses Bragg reflection to band-pass-filter the radiation from a high-intensity, broad-spectrum source.

By the choice of D, θ, and the materials in the layers of the multilayer coats, the monochromator can be made to operate at a desired wavelength in the soft-x-ray or extreme-ultraviolet portion of the electromagnetic spectrum. An additional pair of multilayer reflectors (not shown) could be used to enhance the spectral resolution of the monochromator and to cancel the lateral displacement of the beam; such displacement would be unacceptable in some synchrotron-beam-line or free-electron-laser applications.

The mirrors are nominally tilted at an angle of 45° with respect to the incident beam, but different angles can be chosen for selected wavelengths. The operating wavelength is changed by replacing the pair of mirrors with another pair. Because the mirrors can be quite small (nominally rectangular, 1 cm wide by 2 cm long by 0.5 cm thick), the cost of fabricating the pairs of mirrors can be very low. A collection of pairs of coated mirrors could be made available to enable operation at selectable and precalibrated wavelengths from 20 Å to over 400 Å. Adjustable slits could be mounted in the exit aperture to facilitate control of the spatial extent and intensity of the emerging beam.

This work was done by Richard B. Hoover of **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28499/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

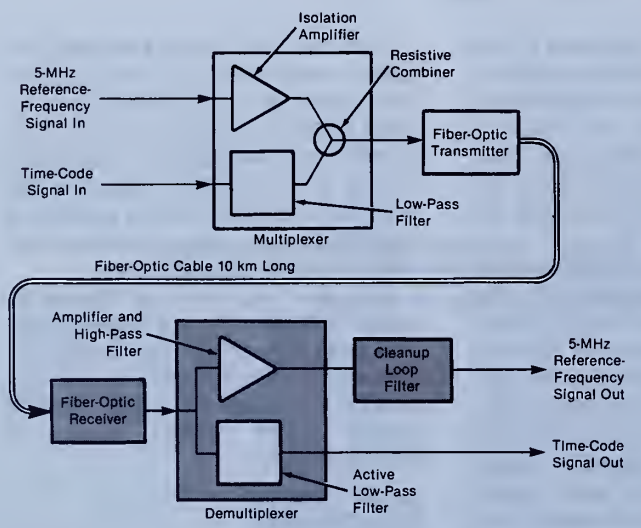
Diplex Fiber-Optic Link for Frequency and Time Signals

Relatively inexpensive equipment delivers signals of high quality.

Reference frequency and time signals are transmitted simultaneously from a central signal-processing station along a 10-km fiber-optic link to a remote station. The diplex fiber-optic link is part of the Goldstone Deep Space Communications complex; similar links may be useful in television, communication, and electric-power-distribution networks and other applications in which signals at different locations must be synchronized precisely.

The fiber-optic link consists mostly of commercial equipment, some of which is modified slightly; because of this, its cost is relatively low. At the central station, a signal combiner adds the 5-MHz reference-frequency signal and the 36-bit time-code signal, forming a composite signal, which modulates the light transmitted along the optical fiber. At the remote station, the fiber-optic receiver detects the composite signal and provides the input to a diplexer, which separates the frequency reference signal from the time-code signal. The signals are then amplified to the desired levels. Despite the relatively low cost of the fiber-optic equipment, the stability of its output reference-frequency signal is greater than that of a prior cesium frequency standard.

The figure illustrates the operation of the system in more detail. The 5-MHz reference-frequency signal is fed to the combiner through an isolation amplifier: this prevents the time-code signals from feeding back into the reference-frequency source, where they would give rise to cross modulation between the two signals. The time code signal is fed to the combiner through a low-pass filter with a cutoff frequency of 10 kHz. The signal combiner is of the resistive type to minimize intermodulation distortion (the amount of intermodulation distortion produced by a transformer-type combiner would be excessive in this application).



Time-Code and Reference-Frequency Signals are transmitted in diplex along an optical fiber and recovered at the remote end.

In the fiber-optic transmitter, the optical carrier emitted by a laser diode is amplitude-modulated with pulses at a subcarrier frequency of 24 MHz. The output of the signal combiner is used to frequency-modulate the subcarrier. The optical signal modulated by the frequency-modulated subcarrier is transmitted along the optical fiber. In the receiver at the remote station, a photodiode detector recovers the frequency-modulated subcarrier from the optical signal, and a frequency discriminator recovers the modulation.

To recover the separate time-code and reference-frequency signals, the output of the receiver is fed to a two-branch demultiplexer. In one branch, a low-pass active filter extracts the time-code signal. In the other branch, the signal is amplified and passed through a high-pass filter with a cutoff frequency of 100 kHz to obtain a "dirty" version of the 5-MHz signal that is partially contaminated with the time code. The time-code contamination is removed, and the noise bandwidth is reduced by a cleanup loop filter, which consists of a quartz frequency-standard oscillator locked in phase to the "dirty" 5-MHz signal.

This work was done by George F. Lutes and Malcolm D. Calhoun of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-18180/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

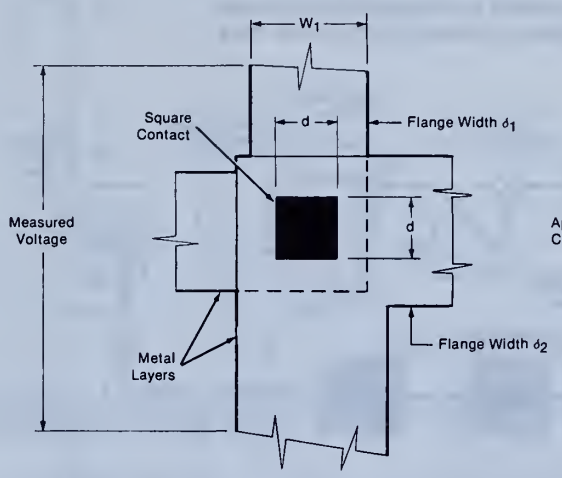
Flange Correction for Metal-to-Metal Contacts

Interfacial resistances can be extracted more accurately from four-terminal measurements.

An improved mathematical model provides a correction for the flange effect in estimating the resistance of a square contact between two metal layers from standard four-terminal measurements. The model is an extended version of one developed previously for a contact between a metal layer and a semiconductor layer, wherein the flange effect is important in the semiconductor layer only. Here the flange effect in both metal layers is significant.

As its name suggests, the flange effect occurs in the flanges — the regions of the metal layers in the vicinity of the contact — and is caused by the lateral flow of electrical current in these regions. In the one-flange (semiconductor/metal contact) model, the metal layer is represented by an equipotential plane, the contact zone is shrunken slightly from its true dimensions to a smaller equipotential core embedded in the semiconducting layer modeled as a two-dimensional resistive sheet, and a lumped resistor represents the interfacial resistance. The shrinkage of the core from the original contact zone is given by effective lengths of current flow under the contact derived from a one-dimensional-transmission-line model.

The two-flange (metal/metal contact) model is obtained by piecing together two one-flange models, one for each metal layer. Mathematically, this alters the effective lengths and implicity distributes the interfacial resistance between two one-flange problems. The two-flange model has been tested by comparison with numerical simulations and with experiments. The resistances predicted by the model were found to agree with those of the simulations at contact sizes of 1 and 4 μm but to disagree somewhat with those of the simulations at intermediate sizes. However, the predictions of the model agreed with measurements in the same size range.



The **Four-Terminal Method** is a standard method for measuring the resistance of a contact like this one between the two metal layers. The resistance of the contact is determined by applying a current and measuring the voltage as shown, then making a correction for the geometry.

This work was done by Udo Lieneweg and David J. Hannaman of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-18052/TN*

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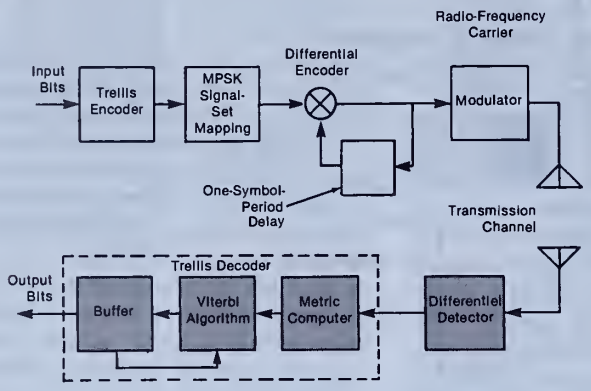
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Multiple-Symbol Detection of Multiple-Trellis-Coded MDPSK

An increase in the observation time would reduce the probability of error.

Figure 1. The **Multiple-Trellis-Encoding and -Decoding Subsystems** are similar to those described previously in *NASA Tech Briefs*, except that the observation time for detection is increased from 2 to 3 or more symbol periods.



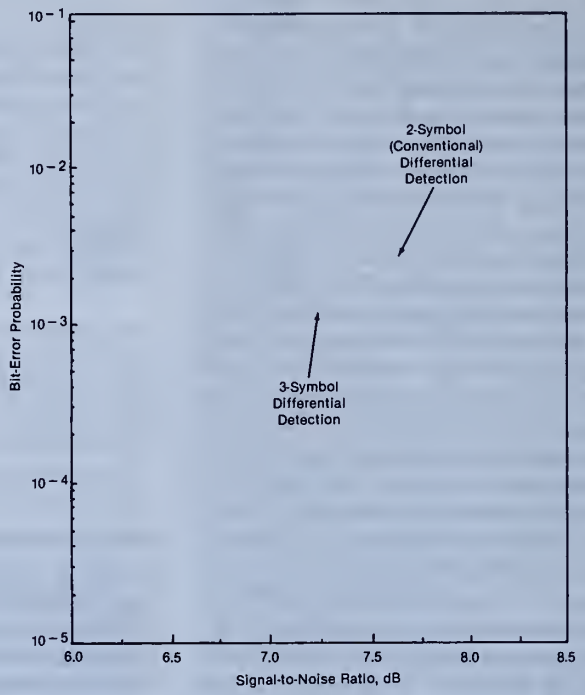


Figure 2. The **Performance of a System** like that of Figure 1 was determined by computer simulation. The simulated system used **8PSK** with a 16-state, rate-2/3 trellis-code that had an interleaving size of 512 symbols and an interleaving depth of 16 branches. It was assumed that the transmission channel was characterized by additive white gaussian noise and introduced no significant spurious phase modulation during the detection time of 2 or 3 symbol periods.

In a proposed scheme for the detection and decoding of multiple-trellis-coded multilevel differential-phase-shift-keyed (MDPSK) radio signals, the observation time for differential detection would be extended from the conventional 2 to a larger number of symbol periods. This represents an extension of a previous scheme to decrease the rate of error in differential detection of uncoded MDPSK by increasing the number of symbol periods.

Figure 1 illustrates the roles of the various transmitting and receiving subsystems in the proposed scheme. Input bits occurring at a rate R_b would pass through a rate-$[nk/(n+1)k]$ multiple-trellis encoder (where k is the multiplicity of the code), producing an encoded bit stream at a rate $R_s = [(n+1)k/nk]R_b$. Next, the encoded bits would be divided into k groups of $n+1$ bits each, and each group would be mapped into a symbol selected from an $M = 2^{n+1}$-level PSK signal set according to a set-partitioning method for multiple trellis codes analogous to that proposed for conventional ($k = 1$) codes. Inasmuch as the MDPSK symbol rate would be R_b/n, it is reasonable, from a perspective of equal bandwidths, to compare the expected performance of this system with that of an uncoded $M = 2^n$-level DPSK system that has the identical input bit rate.

At the receiver, the noise-corrupted signal would be differentially detected, and the resulting symbols would be fed to the trellis decoder, which would be implemented as a Viterbi algorithm. In the selection of a decoding metric, there is a tradeoff between simplicity of implementation and the optimality associated with the degree to which the metric matches the statistics of the output of the differential detector. For uncoded MDPSK, a metric based on minimization of the distance between the received and transmitted signal vectors is optimum in the sense of a minimum-probability-of-error test. For conventional trellis-coded MDPSK, the metric takes on the form of a minimum-squared-Euclidean-distance metric. For multiple-symbol detection of multiple-trellis-coded MDPSK, the form of the metric is quite different, but this metric can be converted once again into a minimum-squared-Euclidean-distance metric by a modification of the multiple trellis code. The so-called "equivalent" multiple trellis code that results from this modification then becomes the principal concept used in analyzing the performance of the overall system.

Figure 2 illustrates the computed performances of a representative system with 2- and 3-symbol detections. For the range of bit-error probabilities shown, the slight increase in the observation time from 2 to 3 symbol periods decreases the bit-error probability by an amount equivalent to a decrease of about 0.75 dB in the signal-to-noise ratio.

This work was done by Dariush Divsalar, Marvin K. Simon, and Mehrdad M. Shahshahani of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-18043/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Self-Injection Locking of Diode Lasers

Several modes are locked to a single spatial mode and frequency.

A simple optical coupling scheme locks an array of gain-guided diode lasers into oscillation in a single mode and with a single-lobed output beam. One application of the new scheme is for pumping of neodymium: yttrium aluminum garnet lasers with diode-laser arrays.

Typically, an array of gain-guided diode lasers emits a beam of light characterized by a spectrum of multiple longitudinal-mode frequencies and dual-lobe far-field spatial pattern. However, it is usually desirable to concentrate the energy of the output beam into a single longitudinal mode and a single spatial lobe in the far field. In the simplified coupling scheme, selective feedback from a thin etalon self-injection-locks the array into the desired mode.

The concept was tested in experiments with arrays of 10 and 20 diode laser stripes in the configuration shown in Figure 1. The temperatures of the arrays were maintained within ±0.1 °C of a preset value. Figure 2 shows the results of one of the experiments: Once the etalon was carefully aligned, four of the five wavelength modes were suppressed, and the two lobes of the main beam were combined into a single lobe.

This work was done by H. Hemmati of Caltech for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17665/TN.

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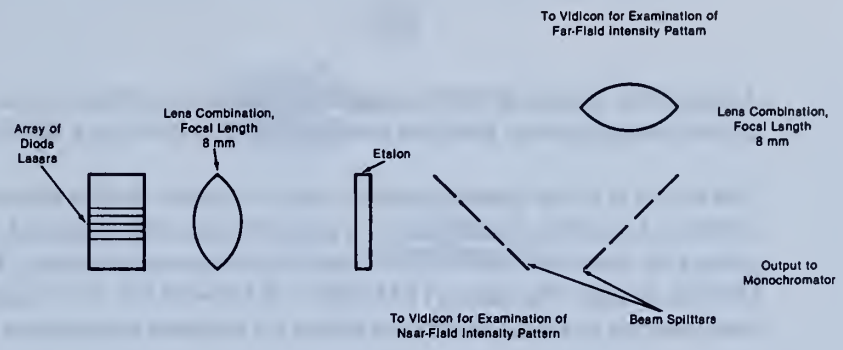
To Vidicon for Examination of Far-Field Intensity Pattern
Array of Diode Lasers
Lens Combination, Focal Length 8 mm
Etalon
Lens Combination, Focal Length 8 mm
Output to Monochromator
To Vidicon for Examination of Near-Field Intensity Pattern
Beam Splitters

Figure 1. An **Array of Diode Lasers** is self-injection-locked to a single mode by feedback from a thin etalon.

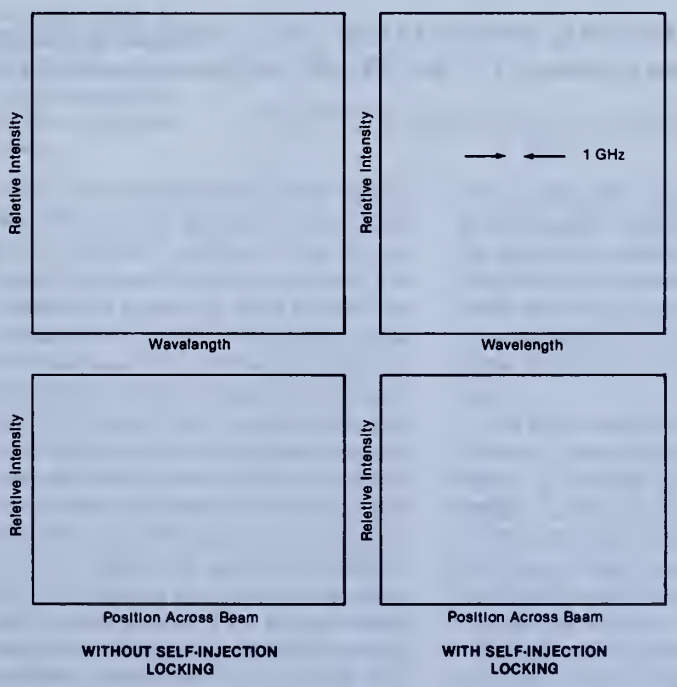

Figure 2. The **Spectrum and Spatial Modes** of the array are shown with and without self-injection locking of the type illustrated in Figure 1.

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Technology Application

Fermi National Accelerator Laboratory

High Speed, Low Noise ASIC Preamplifier

A high speed, low noise readout system for silicon strip detectors was developed for a Fermilab fixed target experiment designed to study the production of B hadrons by a 800 GeV/c proton beam.

This device is a four channel amplifier chip for particle physics silicon strip detectors developed using the Tektronix Quickchip 2 technology for application specific integrated circuits (ASIC). The system uses a bipolar process for good noise characteristics and high frequency response. The power dissipation of the amplifier is 47 MW per channel. The gain is 17 MV/FC with CIN=20 PF. A new approach is incorporated which makes use of laser trimmed nichrome resistors to reduce the response sensitivity to process variations in chip resistance.

The preamplifier has consistent impulse response over a wide range of resistance process variations. It also has faster response and lower noise. The main application for this device is high energy physics.

FOR ADDITIONAL INFORMATION: Office of Research and Technology Applications, Fermi National Accelerator Laboratory, P.O. Box 500, MS 208, Batavia, IL 60510; (312)840-3333. Refer to FAA-550/TN.

NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

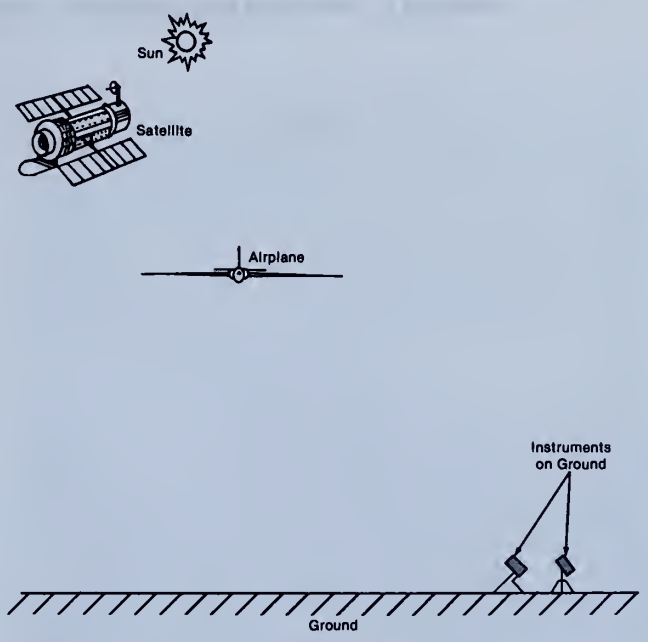
Airborne Calibration of an Orbiting Radiometer

Measurements enable compensation for degradation of optics and changes in detector circuitry.

An experiment has demonstrated the feasibility of using a recently calibrated airborne radiometer to calibrate a satellite-borne radiometer that monitors the Earth and that has not been calibrated since before launch. The calibration technique helps to assure Earth scientists of the accuracy of satellite radiometric measurements taken during a long time. The optical train of the orbiting radiometer is degraded slowly and the sensitivities of detectors and gains of amplifiers are changed slowly in the outer-space environment, but frequent calibrations by the airborne-radiometer technique make it possible to compensate for these changes.

In concept (though not in implementation) the calibration technique is simple. The airborne and spaceborne radiometers simultaneously monitor the same target area on the Earth during clear weather. The target is preferably bright and relatively uniform. The aircraft measurements are made from as high an altitude as possible along the same viewing vector as that of the satellite (see figure), so that the airborne and spaceborne radiometers measure nearly identical spectra, including the effects of the atmosphere. The radiances measured by the airborne radiometer are corrected for what little part of the atmosphere lies above the aircraft. The spaceborne radiometer is then calibrated by comparing its measurements with the corrected measurements taken by the presumably-accurate airborne radiometer.

In the experiment, a radiometer was flown aboard a U-2 airplane at an altitude of 19.8 km to calibrate the visible and near-infrared spectral band of the Visible-Infrared Spin-Scan Radiometer (VISSR) aboard the Geostationary Orbiting Environmental Satellite 6 (GOES-6), which produces images of an entire hemisphere once each hour in three spectral bands to provide nearly global observations of clouds, water vapor, and temperatures. White Sands, New Mexico, was selected as the target area for several reasons: It has the required brightness and near uniformity; the probability of a clear sky there is great; the characteristics of the atmosphere there have been well documented for years; the reflectance of the surface is diffuse and nearly Lambertian, and, consequently, any errors that arise from slight differences between the fields of view of the airborne and spaceborne radiometers are minimal; and the radiance of this area lies in the higher dynamic range of the spaceborne radiometer. The airborne and spaceborne radiometric measurements were supplemented with surface meteorological data, including horizontal visibility and soil moisture, and with other meteorological data.



The **Same Area of the Earth** is viewed along the same direction by a spaceborne and an airborne radiometer.

The satellite and aircraft measurements were processed and compared to obtain calibration coefficients. The results showed that the radiances measured by the airborne radiometer were of the order of 14 percent greater than those measured with the spaceborne radiometer, using its original calibration. Assuming that the spaceborne radiometer was calibrated correctly before launch, this means that it had lost some sensitivity in orbit, as one might expect.

This work was done by Gilbert R. Smith, Robert H. Levin, Robert S. Koyanagi, and Robert C. Wrigley of **Ames Research Center**. *Further information may be found in NASA TM-101064 [N89-25494], "Visible and Near-Infrared Channel Calibration of the GOES-6 VISSR Using High-Altitude Aircraft Measurements."*

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Energy

0789 Improved Solar Thermal Receiver Shows High Efficiency

0790 SPR Technology Used to Make Natural Gas Storage Facility

0791 Stacking Oxygen-Separation Cells—Solid-electrolyte units feature decreased complexity in structure and assemble. (Licensing Opportunity)

Sandia National Laboratory

Improved Solar Thermal Receiver Shows High Efficiency

A device that converts sunlight to heat has been made more efficient than earlier designs and better able to cope with natural fluctuations in sunlight such as that caused by a passing cloud.

In recently completed tests at Sandia National Laboratories, the experimental solar thermal device—called the reflux pool-boiler receiver—achieved an efficiency of about 90 percent in converting the sun's energy to heat. The results are an improvement over other solar receivers operating under similar conditions.

"All things being equal—such as aperture size, operating temperature, and input power—this is a much more efficient receiver technology," says Richard Diver of Sandia's Solar Thermal Electric Technology Division.

Receivers turn concentrated sunlight reflected from a mirrored parabolic dish into heat that can be used by an engine to generate electricity.

The test results represent a breakthrough in the development of reflux receivers, a relatively new concept in solar receiver design that was invented at Sandia. The improved reflux pool-boiler receiver was designed and built by Sandia researchers and works much like a stovetop double boiler. Used in a solar thermal system, the receiver would be paired with a Stirling Cycle engine.

Unlike other receivers, the reflux pool-boiler receiver uses a pool of liquid metal—in this case, molten sodium—to transfer heat from the face of the receiver to the helium-filled heater tubes of the Stirling engine. As the liquid metal boils, it vaporizes and then condenses on the heater tubes. Condensed liquid drips back into the "pool" by gravity, thus the term "reflux."

Stable boiling is the key

An advantage of the pool-boiler is that it transfers heat uniformly to the Stirling engine's heater head tubes, allowing for a higher engine temperature and greater engine efficiency. Its use of both a liquid and a vapor result in a uniform temperature throughout the boiler and make it capable of handling very high heat input.

Earlier versions of the pool-boiler system have experienced problems with sudden, explosive boiling in the pool and widely fluctuating temperatures. Explosive boiling can occur when boiling a metal on a metal surface, according to Charles Andraka. The instability produces temperature variations, which are exacerbated by inconsistencies in sunlight reaching the receiver, such as when a cloud passes over the sun, he says.

The reflux pool boiler has been tested on-sun using one of Sandia's research parabolic dishes. The receiver is mounted at the focus of the dish in the upper right corner of the photo.

"The trick is to get stable boiling, and we've successfully demonstrated it both in the laboratory and on-sun," Andraka says. Other Sandians involved in the project were James Moreno, W. Craig Ginn, Vernon Dudley, and Scott Rawlinson.

Boiling stability was achieved by adding minute cavities to the interior surface of the stainless steel dome of the 75-kilowatt receiver. An electric discharge machine was used to produce 35 cavities, each 0.15 millimeters in diameter, 0.5 millimeters deep and 10 centimeters apart in the 41-centimeter-diameter dome.

Since the bottoms of the holes are closer to the hotter outer surface of the receiver dome, they provide a more hospitable site for the stable formation of sodium gas bubbles than does the smooth surface alone, Andraka says. As soon as a bubble leaves the cavity, liquid sodium flows back in the cavity, starting the process all over again. The depth and temperature of the cavity prevents sodium from reaching the bottom before the next bubble begins to inflate. The result is consistent boiling at the rate of about 10 bubbles per second at each cavity.

"Having this artificial cavity in the surface was the key to stabilizing boiling," Andraka says. The idea was proposed at the Massachusetts Institute of Technology more than 20 years ago but had not been applied to a practical device until now, he says.

During tests, the receiver was mounted at the focus of Sandia's test bed concentrator, a parabolic dish used for research purposes.

The receiver efficiency was about 90 percent when operated at full power and 800° C. Sudden, explosive boiling and vaporization were avoided.

Future pool-boiler activities at Sandia will involve refining fabrication techniques and investigating other ways of promoting boiling stability. The ultimate goal is to produce a receiver that has long life, low cost, and manufacturable design.

Sandia is the DOE's lead laboratory for reflux receiver and solar-electric technology. *Technical contacts:* Charles Andraka, 505-844-8573, or Richard Diver, 505-846-0215. □

FOR ADDITIONAL INFORMATION

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Refer to announcement 26 No. 4

Sandia National Laboratory

SPR Technology Used to Make Natural Gas Storage Facility

Technologies developed by Sandia National Laboratories for the U.S. Department of Energy's Strategic Petroleum Reserve have been used for the first time by private industry to create an underground facility for storing natural gas.

The facility is a cavern leached out of a subterranean salt dome on the Texas Gulf Coast. Such formations have characteristics that make them excellent structures for hydrocarbon storage. The salt is relatively easy to hollow out, and its natural sealing qualities do not permit the hydrocarbons to escape as they would through permeable rock.

The DOE's Strategic Petroleum Reserve (SPR) was developed in the late 1970s and early 1980s to store as much as 750 million barrels of oil in salt formations in Texas and Louisiana. The rationale behind the SPR is to offset immediate national economic effects of an interruption in the supply of imported oil.

Sandia's role in the SPR project has been to qualify existing caverns for oil storage capability and to design new caverns and a system for retrieving the oil. In the case of the SPR storage sites, 47 new caverns were created and 16 existing ones—created mostly for brine operations—have been tested and qualified.

The caverns were created by a process called leaching. Surface water pumped into the formation dissolves the salt, and the brine is then pumped out of the formation through deeper pipes.

Oil, gas storage different

Jim Linn, supervisor of Sandia's Underground Storage Technology Division, says Tejas Power Corporation was aware of Sandia's SPR work and approached the Labs in 1989 about serving as a geotechnical consultant on an underground storage cavern project about 30 miles east of Houston.

Tejas Power, which gathers and processes natural gas for sale to pipelines and distribution companies, had entered into a joint venture with Philbro Energy Inc. to create Moss Bluff Gas Storage Systems. The venture acquired a small cavern that had been drilled and started by another company in the early 1980s. That project was discontinued, and the well was plugged.

The initial project was designed primarily for oil storage. A cavern designed for natural gas storage requires a different configuration from one designed for oil storage, Linn explains.

"With oil storage, you want to store as shallow as possible, making recovery easy, so you design a vertical cavern that is as close to the surface as possible. With gas, you want a deeper cavern, which provides greater pressure and allows a greater volume of gas to be stored. But as you go deeper, salt creep becomes a problem and cavern volume is lost, so the optimum depth and shape becomes a compromise between pressure and salt creep," he explains.

To determine these specifications, the Moss Bluff partners called upon Sandia because they knew it had dealt with these issues in the SPR project. Linn explains that Tejas Power and Philbro also hired private engineering firms to work on the Moss Bluff project but that Sandia has some calculation capabilities and experience that Tejas could not get through private industry.

"Essentially we supplied a leaching plan for Moss Bluff," says Jim Todd, one of the Sandia engineers who worked on the project. "We ran a computer code developed at Sandia that simulates the leaching process, and with that code we could predict the shape of the cavern using certain string settings and injection techniques.

"We calculated maximum cavern pressures, selected the cavern roof location and cavern depth, and determined the required cavern diameter to get the desired volume and cavern stability. We also analyzed what sort of surface subsidence can be expected," Todd explains.

Work began on the project in September 1989, and a ceremony marking the filling of the cavern with 1.8 billion cubic feet of gas was held in December 1990. But the ceremony may not mark the end of Sandia's involvement with Moss Bluff, Linn says. Two more caverns are being planned to expand the storage capacity at the site to 8 billion cubic feet. Sandia may continue to serve as geotechnical consultant for those caverns.

FOR ADDITIONAL INFORMATION: Contacts: Jim Linn (505)844-6813 and Jim Todd (505)846-1810, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Stacking Oxygen-Separation Cells

Solid-electrolyte units feature decreased complexity in structure and assembly.

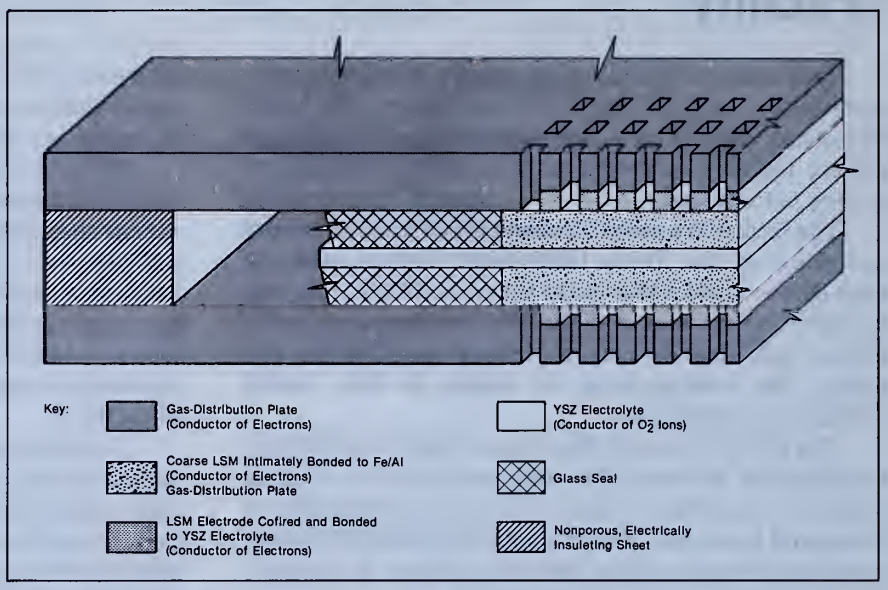
A simplified configuration and procedure have been developed for the assembly of stacks of solid-electrolyte cells that separate oxygen from air electrochemically. A previous, more complicated version of such a cell is described in "Improved Zirconia Oxygen-Separation Cell" (NPO-16161), *NASA Tech Briefs*, Vol. 12, No. 4 (April 1988), p. 42. The new configuration and procedure reduce the number of components and thus reduce the probability of such failures as gas leaks, breakdown of sensitive parts, and electrical open or short circuits.

Electrode and electrolyte layers are stacked alternately. Such essential features as seals, gas-distribution channels, and manifolds are built into the components; they do not have to be added externally. The electrode material is strontium-doped lanthanum manganite (LSM). The electrolyte is yttria-stabilized zirconia (YSZ).

First, an inner sandwich of LSM/YSZ/LSM (see figure) is made. The sandwich is placed in a fixture, and a recess about 1 mm wide is etched or removed mechanically around the rim of each LSM layer. Glass powder in an organic binder, which will be heated subsequently to make an edge seal, is applied to these recesses.

A gasket of nonporous, electrically insulating material is placed around the edge of a gas-distribution plate. Made of dense iron/aluminum or nickel/aluminum alloy, the electrically conductive plate contains an array of channels.

The LSM/YSZ/LSM sandwich, its rim coated with the glass powder, is placed on the gas-distribution plate. A second gas-distribution plate, also gasketed, is placed on top of the LSM/YSZ/LSM sandwich. Sandwiches and gas-distribution plates are added to the stack until the requisite number of cells have been assembled.


Key:
Gas-Distribution Plate (Conductor of Electrons)
YSZ Electrolyte (Conductor of O_2^- Ions)
Coarse LSM Intimately Bonded to Fe/Al (Conductor of Electrons) Gas-Distribution Plate
Glass Seal
LSM Electrode Cofired and Bonded to YSZ Electrolyte (Conductor of Electrons)
Nonporous, Electrically Insuleting Sheet

One Cell of a multicell stack includes an electrolyte layer between two electrode layers. Gas-distribution plates above and below the electrodes bring reactants to and from the surfaces of the electrodes.

As the stack is brought up to operating temperature, the glass powder turns into a nonporous seal around the rim. The stack is compressed during heating to ensure that the glass spreads out to form the seal and that an intimate contact of low electrical resistance forms between the gas-distribution plates and the electrode/electrolyte sandwiches.

This work was done by James E. Schroeder of Caltech for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17223/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Engineering

0792 High-Security Lock Designed

0793 Parachute Release Mechanism Designed

0794 Security Assessment System Developed

0795 Polyurethane Foam Roofing Systems

0796 Artificial Dissipation in Computations of Hypersonic Flows—Four schemes are tested on strong shocks.

0797 Electromagnetic Gun With Commutated Coils—Greater speeds should be attainable.

0798 Sorption Compressor With Rotary Regenerator—Features would include less required power and greater reliability

0799 Reducing Thermal Conduction in Acoustic Levitators—Piezoelectric driving elements would be protected from excessive temperatures. (Licensing Opportunity)

0800 Mixed-Gas Sorption Joule-Thomson Refrigerator—Features would include relative simplicity, less required power, and no vibration. (Licensing Opportunity)

0801 System Would Keep Telescope Reflector Segments Aligned—Actuators would adjust segments in response to sensed positions.

Testing & Instrumentation

0802 Fiber-Optic Hydrophone Developed

Other Items of Interest

0827 Abandoned Mine Lands Program TN#1 Subsidence Abatement Investigation Laboratory (SAIL)

High-Security Lock Designed

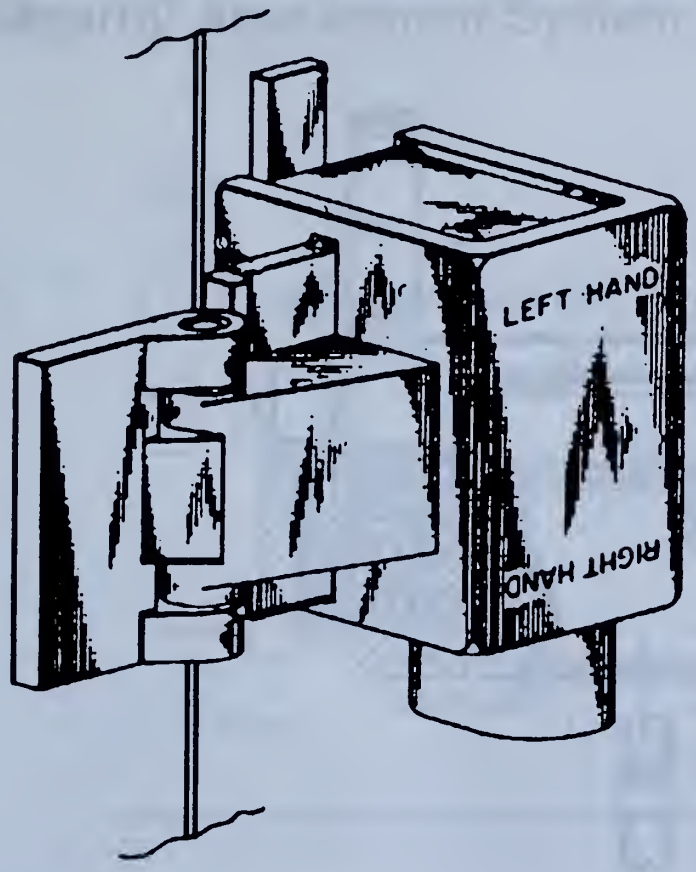

Figure 2. High-security lock

The Naval Weapons Support Center (NWSC), Crane, Indiana, which is an arm of the Naval Sea Systems Command (NAVSEA), has developed an improved lock (Figure 2) for areas requiring high security. The lock is immune to methods typically used to break into areas secured by conventional padlocks. Lock shackle pins are rigidly secured to a door jamb. A strong metal cover assembly is securely attached to the door in a position to cover the shackle pins when the door is closed. The cover has a side opening large enough to admit the pins, but too small for a lock to pass through. The cover has a bottom opening for insertion of a cylindrical lock to engage the shackle pins to secure the door. Access to crowbars commonly used to break conventional padlocks and hasps is denied by the improved lock, which is widely used by the Navy. The lock is universal and can be mounted on either the left or right side of a door or other closure.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
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Refer to 160304/TN

Parachute Release Mechanism Designed

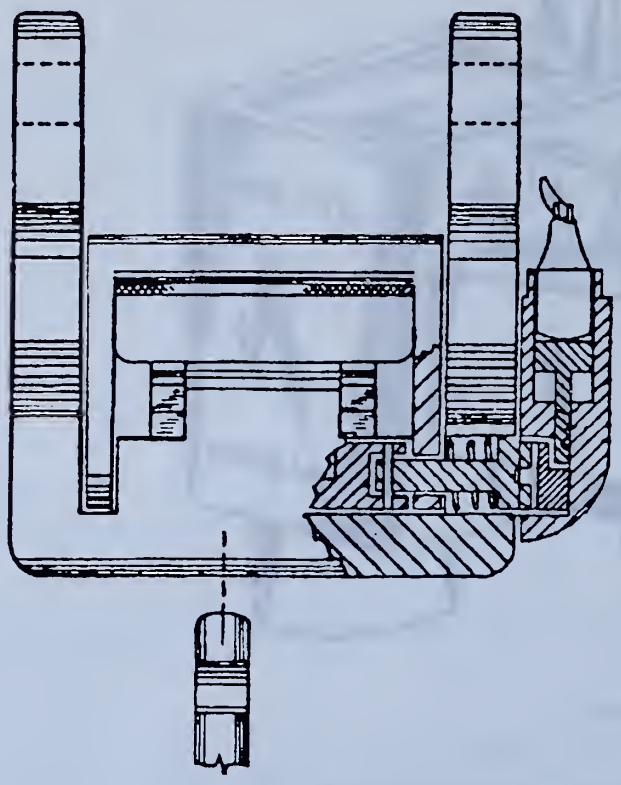

Figure 3. Side-mounted, automatic power release attachment

The Naval Ocean Systems Center (NOSC), San Diego, California, has designed a release mechanism to be mounted to the side of an existing parachute release connector as a power attachment to provide automatic separation of parachute and pilot in compliance with an initiation signal (Figure 3).

This device will enable a parachutist, who is injured or otherwise unable to manually operate the connector, to be released automatically. Interlock means are provided to secure the rotatable shaft in an unlocked position after it has been operated by a self-contained power source to prevent inadvertent reuse with an expended power source. This device has a low profile configuration offering minimum obstruction and discomfort.

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Refer to 160305/TN

Security Assessment System Developed

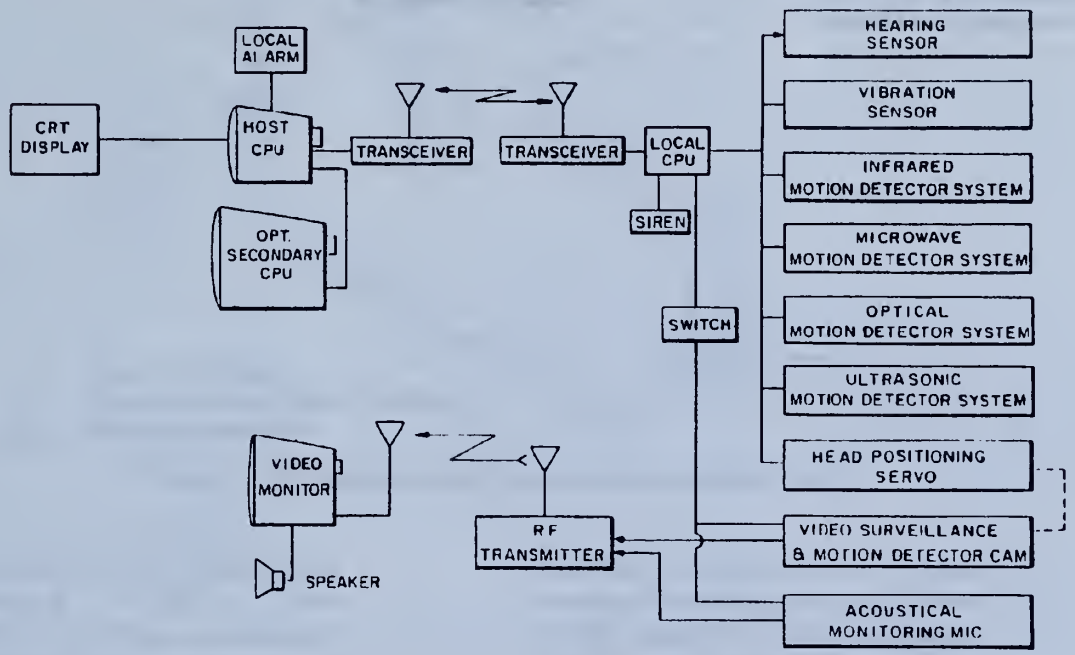

Figure 2. Intelligent security assessment system

The Naval Ocean Systems Center (NOSC), San Diego, California, has developed a security assessment system (Figure 2) that provides a multisensor detection, verification, and intelligent assessment capability for a mobile security robot or stationary alarm system. The new system exhibits a high probability of detection with the ability to distinguish between actual and nuisance alarms. Because the likelihood of false alarms is minimized, the sensitivity of each intrusion sensor can be raised.

Each of the sensors operates on a different principle to detect intrusion. For example, sound, vibration, infrared, microwave, and light-level sensors are used. A computing system receives the outputs of each of the sensors and is programmed to provide an output indication of intrusion by the intrusion sensors. Each sensor state is evaluated, and the system assigns a weighting factor for each sensor that is in the *on* state. The computing system sums the weighting factors, compares this sum to a reference, and then provides a further output when the

sum exceeds the reference. This computing system output is used to activate an additional intrusion detector such as an ultrasonic detection system and also to activate and automatically position a video surveillance camera for observance of the area where the intrusion is indicated.

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NAVY
Domestic Technology Transfer Fact Sheet

Polyurethane Foam Roofing Systems

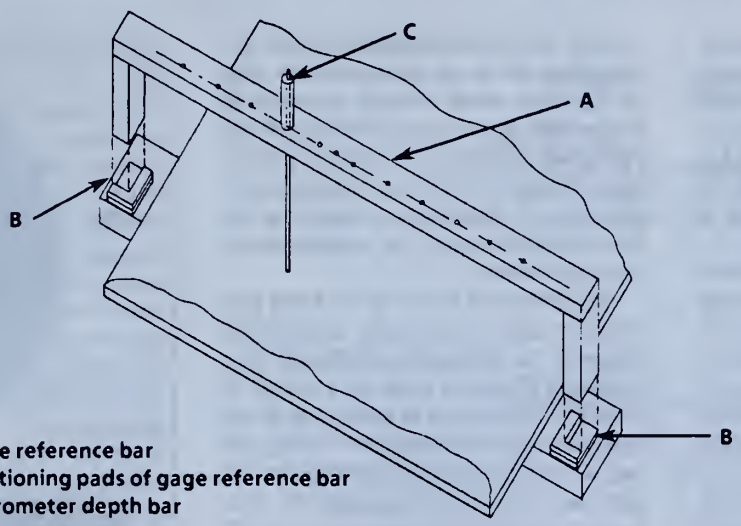

Figure 1. Device for measuring uncoated urethane foam

The Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California, analyzed the performance and properties of spray-applied polyurethane foam roofing systems (Figure 1). Polyurethane foam analyzed included densities of 2.0, 2.5, and 3.0 pcf. Elastomeric coating systems included catalyzed silicones, moisture-curing silicones, a water-based silicone, butylhypalons, hypalons, acrylics, neoprene-hypalon, butyls, chlorinated rubber, fibrated aluminum-asphalt, catalyzed urethanes, moisture-curing urethanes, urethane-hypalons, neoprene asphalt-acrylic emulsion, rapid-cure urethanes. A rigid cementitious coating system was also included. Properties of the coating system such as adhesion, tensile strength, wind-driven-rain absorption, impact strength, and elongation were also analyzed.

After exposure periods of up to almost 12 years, eleven of the 54 coating systems were rated excellent or very good at all three of the exposure sites—seashore, desert, and mountain. They included catalyzed silicone with granules, moisture-curing silicone with granules, two acrylic emulsions, three acrylic emulsions with granules, two catalyzed urethanes, one moisture-curing urethane with granules, and a urethane-silicone. Effects of foam density and relative importance of physical properties on coating system performance are also analyzed as well as degradation of uncoated foam.

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Refer to 160401/TN

NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Artificial Dissipation in Computations of Hypersonic Flows

Four schemes are tested on strong shocks.

Four artificial-dissipation mathematical models have been introduced to suppress spurious numerical oscillations in finite-difference computations of hypersonic external flows. The models were tested for their effects in capturing the details of shocks in hypersonic flows about bodies of various shapes (see figure).

The mathematical context is the lower-upper/symmetric-Gauss–Seidel (LU-SGS) algorithm for the solution of the Navier–Stokes equations of flow in two dimensions. Within this context, a variety of schemes can be developed by choices of difference operators, Jacobian matrices, and inviscid-flux vectors:

- If one uses upwind operators on the split inviscid fluxes on the downwind side and true Jacobian matrices on the upwind side, one obtains an upwind LU-SGS scheme.
- If one uses upwind operators on the split inviscid fluxes on the downwind side and approximate Jacobian matrices on the upwind side, one obtains a semiupwind LU-SGS scheme.
- If one uses central difference operators on the unsplit inviscid fluxes on the downwind side and approximate Jacobian matrices on the upwind side, one obtains a hybrid LU-SGS scheme.

In the first-and-third-order-dissipation model, third-order terms formed from fourth differences provide background damping. First-order terms are added by second differences under the control of a pressure-sensor term, to which the low-order coefficient is proportional.

The directionally-scaled-dissipation model has the same structure as that of the original first-and-third-order-dissipation model, except for the scaling factor. The use of directional scaling provides anisotropic dissipation to each direction, resulting in improved performances on meshes, the cells of which have high aspect ratios. This model is more accurate on coarse grids than is the first-and-third-order-dissipation model.

In the flux-limited-dissipation model, the dissipative flux is not constructed by adding low-order terms. Instead, functions to limit antidiffusive fluxes are introduced into the high-order terms. The constant parameters of these functions are chosen to provide enough dissipation to suppress numerical oscillations in the neighborhoods of shock waves.

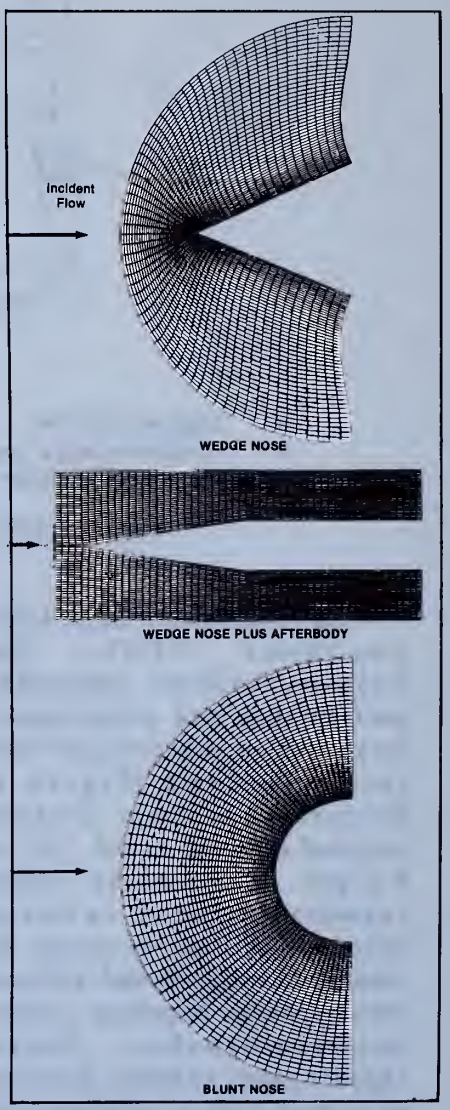
The dissipative fluxes of the three preceding models have scalar coefficients. However, the dissipative coefficient for a system of equations must be a matrix, to meet the requirement of upwinding. In the flux-difference-split-dissipation model, this matrix is constructed by splitting flux differences in a way that separates the characteristic fields that correspond to the different wave speeds. This model and the flux-limited-dissipation model can be regarded as total-variation-diminishing schemes.

The models were tested in a Newton-iteration form of the hybrid LU-SGS scheme. The results of these simulations showed that the flux-limited-dissipation model was robust enough to predict a high-speed flow about a blunt body with strong shock and expansion waves. The flux-difference-split-dissipation model captured shocks with higher resolution but was less robust. The first-and-third-order-dissipation and the directionally-scaled-dissipation models turned out to be neither accurate nor robust enough for computations of flows at high mach numbers.

This work was done by S. Yoon and D. Kwak of **Ames Research Center**. *Further information may be found in AIAA paper 88A-44819, "Artificial Dissipation Models for Hypersonic External Flow."*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

ARC-12260/TN



Hypersonic-Flows About Three Bodies were computed by a finite-difference implementation of the Navier-Stokes equations. Four mathematical models of artificial dissipation were compared in computations on these grids.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Electromagnetic Gun With Commutated Coils

Greater speeds should be attainable.

A proposed electromagnetic gun would include an electromagnet coil, the turns of which would be commutated in sequence along a barrel. Electrical current would be fed to two armatures by brushes sliding on bus bars in the barrel. The interaction between the armature currents and the magnetic field from the coil would produce the force that would accelerate the armature, and the armature, in turn, would push on a projectile. The commutation scheme would be chosen so that the magnetic field would approximately coincide and move with the cylindrical region defined by the armatures (see Figure 1).

The rail- and coil-gun concepts investigated previously have fixed ratios of magnetic field to armature current. In addition, it is necessary to limit the armature current to prevent overheating of the armature. This combination of features limits the attainable accelerating force and, consequently, the muzzle velocity. The proposed scheme has the disadvantage of complexity, but in return, it enables the designer to increase the driving magnetic field without increasing the armature current. In principle, the attainable muzzle velocity could be increased substantially.

The main coil power could be supplied by a pulsed dc generator or a disk-alternator-and-rectifier system. The output of the generator could be fed through electronic switches or brush contacts on a rotating commutator to stationary commutator bars, then through cables from the commutator bars to the turns of the coil. Either the commutator shaft could accelerate or else the spacing between the commutator bars could be decreased in the direction of motion of the brushes to increase the speed of switching as the armature and projec-

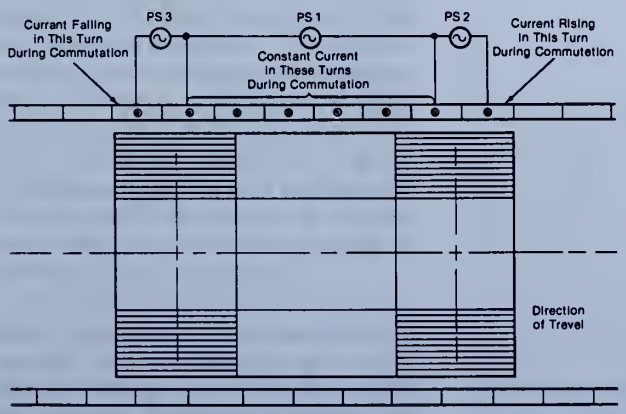
Currant Falling in This Turn During Commutation
PS 3
PS 1
PS 2
Current Rising in This Turn During Commutetion
Constant Current in These Turns During Commutation
Direction of Travel

Figure 1. **Power Supplies Would Be Connected** to turns of an electromagnet coil in a sequence that would match the motion of the armatures.

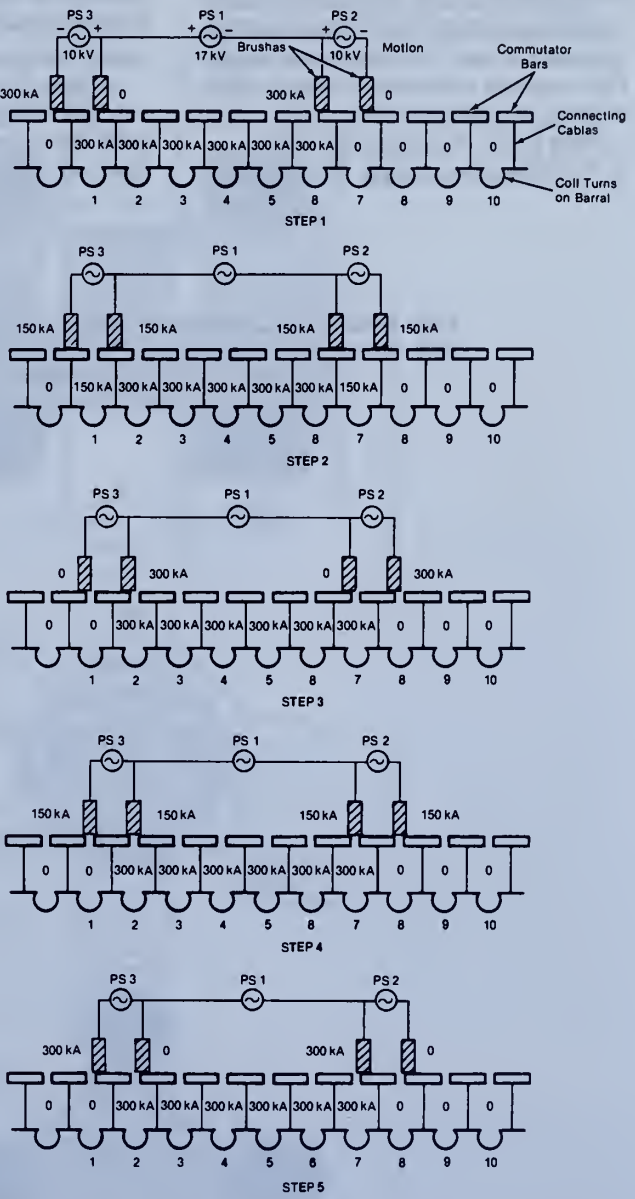

Figure 2. In **One Cycle of the Commutation Sequence** in the system of Figure 1, each brush contact would advance one step to the right.

tile accelerate. On the basis of feedback from an armature-position sensor, a control subsystem could adjust the armature current in such a way as to keep the armature coincident with the traveling wave of current in the coil. The required increase in coil voltage with travel could be provided by increasing the voltage supplied by the generator.

Figure 2 illustrates a typical commutation sequence for a coil commutated mechanically. In step 1, the main power supply, PS1, would be connected to the two inner brushes, supplying full current (300 kA according to one design) to turns 2 through 6. A smaller power supply or a capacitor, PS2, would cause the current in turn 7 to start to rise from zero. Another smaller power supply or a load, PS3, would cause the current in coil 1 to start to fall from the full value (300 kA in this example).

In step 2, the brushes would have moved rightward to the centers of the commutator bars. The current in turn 7 would have risen halfway toward the full value, while that in turn 1 would have fallen halfway from the full value. PS1 would continue to supply full current to turns 2 through 6.

In step 3, the brushes would have reached the right ends of the commutator bars, the current in turn 7 would have reached the full value, and the current in turn 1 would have fallen to zero. During a brief interval in step 4, each brush would touch two adjacent commutator bars, providing paths for the inductively sustained currents. During this interval, the terminals of PS2 and PS3 would be shorted, allowing the currents in PS2 and PS3 to redistribute themselves in transition to the next step. In step 5, the distribution of currents would be like that of step 1 except that the wave of current, the brushes, and the armatures would all have advanced one turn to the right.

This work was done by David G. Elliott of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17839/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Sorption Compressor With Rotary Regenerator

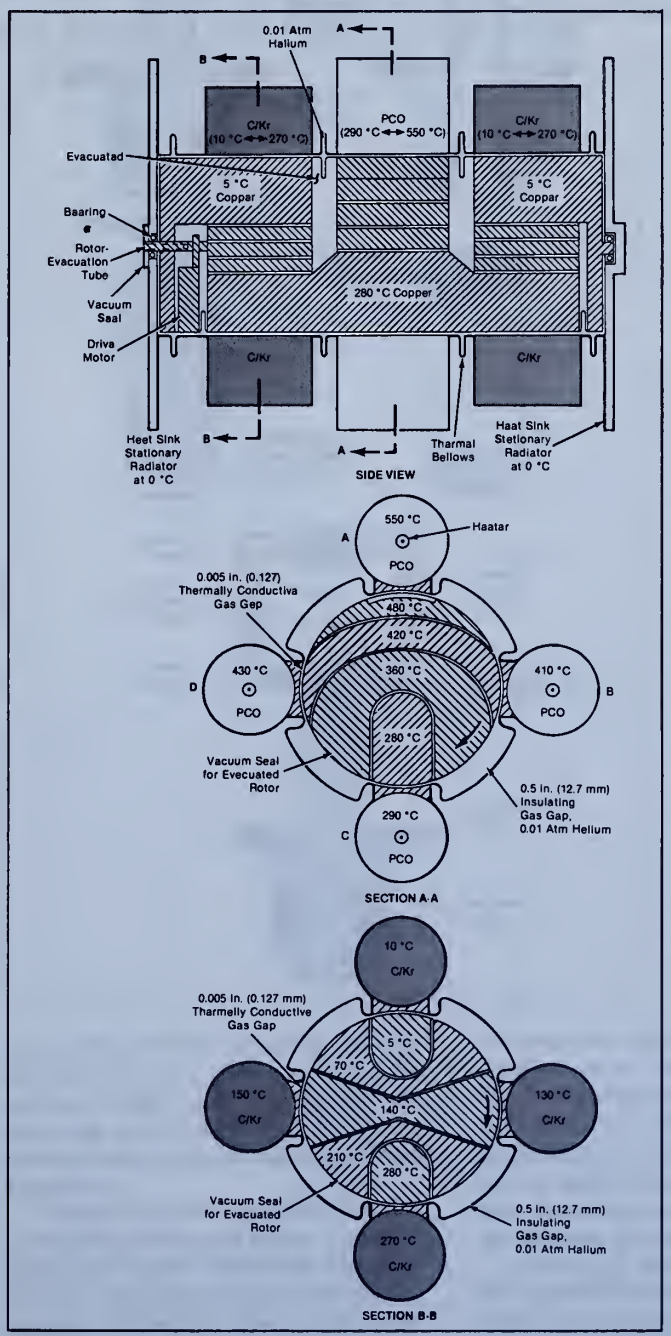
Features would include less required power and greater reliability.

A proposed two-stage sorption compressor for a cryogenic system would feature a rotary regenerator. At each stage, a rotor would interact with a stator to provide quadruple regeneration. A refrigerator based on the proposed compressor would require 35 W of input (heat and electrical power) to produce 1 W of cooling at a temperature of 65 K. This input power is 78 percent less than the 160 W input required by a comparable nonregenerative sorption refrigerator to produce the same cooling effect. The proposed compressor would contain no valves, and the only moving part would be the rotor, which would turn very slowly. Therefore, the compressor should be more reliable than prior compressors have been.

The working fluids of the refrigeration system would be oxygen and krypton. In one stage of the compressor, the stator would contain four praseodymium cerium oxide (PCO) sorption units, which would enforce the circulation of oxygen. In the other stage, the stator would contain four pairs of carbon/krypton (C/Kr) sorption units, which would be powered by waste heat from the PCO units. The PCO units would contain electrical heaters, which would be activated at appropriate phases of the rotation.

The rotor would consist of thermally conductive sections made of copper separated by insulating gaps to effect the phased transfer of heat among the PCO and C/Kr sorption units. The ends of the rotor would be thermally connected to a heat sink in the form of a stationary radiator at a temperature of 0 °C. The insulating gaps in the rotor would be evacuated. The chamber containing the rotor would contain helium gas at a pressure of 0.01 atm (≈1 kPa). Heat would be transferred through the helium gas across gaps 0.005 in. (0.127 mm) wide between the rotor and the sorption units and from the rotor to the heat sinks. Other gaps would be made wider to minimize the transfer of heat.

The rotor would turn intermittently, in angular increments of 45° at intervals of 7.5 minutes, thus completing a cycle every hour. In the figure, the rotor is shown at the 0 °C position. By rotating clockwise 45° from this position, the rotor would establish a conductive path from PCO unit A to PCO unit B. During the ≤ 7.5-minute interval, the temperature of A would be reduced to about 490 °C, while that of B would increase to about 470 °C. Simultaneously, a similar conductive path in the rotor would transfer heat from D to C, causing the temperature of C to rise to about 350 °C



The **Rotary-Regenerator Sorption Compressor** would include a rotor that would transfer heat in phases (in a 1-hour cycle) among sorption units. This compressor would consume less power and be more reliable, in comparison with nonregenerative compressors of similar capacity.

and the temperature of D to fall to about 370°C.

The rotor would then be turned another 45°, causing D to cool to 290°C, at which temperature it would reabsorb O_2. At this phase, B would be electrically heated to 550°C, causing it to liberate O_2. Simultaneously, the rotor would conduct heat from A to C, cooling A to approximately 430°C and warming C to 410°C. Also simultaneously, heat from D would be transferred to the rotor block labeled "280°C." From this block, heat would be transferred to the C/Kr sorption units, which would operate in a manner similar to that of the PCO units. Ultimately, the heat would be transferred from the C/Kr units into the rotor blocks labeled "5°C," then out to the heat sinks at 0°C.

This work was done by Jack A. Jones, Steven Bard, and Ronald G. Ross of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17876/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Reducing Thermal Conduction in Acoustic Levitators

Piezoelectric driving elements would be protected from excessive temperatures.

Acoustic transducers containing piezoelectric driving elements would be made more resistant to heat by reduction of the effective thermal-conductance cross sections of the metal vibration-transmitting rods in them, according to a proposal. Such transducers are used to levitate small objects acoustically for noncontact processing in furnaces. The reductions in the cross sections could also increase the amplitudes of the transmitted vibrations and reduce the loss of heat from the furnaces.

In a conventional piezoelectric transducer, the rod is solid and extends into the furnace (see figure). The transducer is mounted to the furnace housing at the zero-displacement node. Piezoelectric disks in the back section drive the transducer, causing the front face of the rod to vibrate like a piston so that it couples sound waves into the furnace levitation chamber. Unfortunately, the solid core readily conducts heat away from the furnace. This not only reduces the efficiency of the furnace but also increases vulnerability to fatigue at the zero-displacement node and endangers the piezoelectric disks, which depolarize above a critical temperature and no longer function.

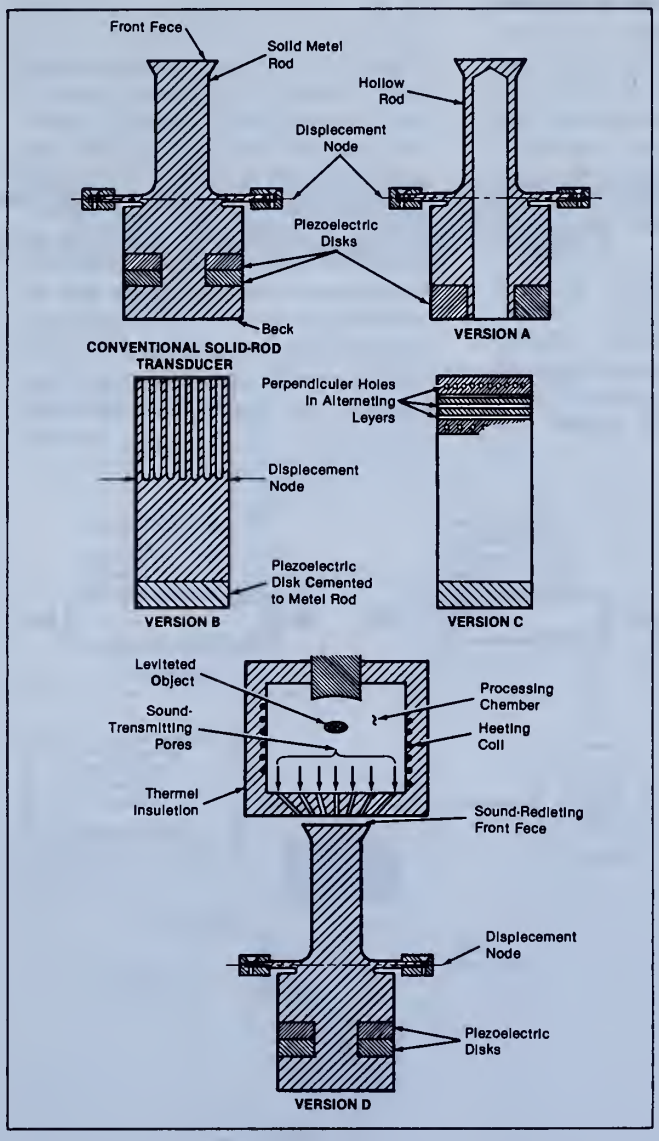
Several versions of the reduced-cross-section configuration are envisioned. In one (version A in the figure), the rod would contain a hollow central core. The cross-sectional area available for the conduction of heat toward the back section would, therefore, be reduced. To prevent the transfer of heat along the core by convection, the core would not be made to extend through the front face. The end of the core, just behind the front face, would be made conical or hemispherical to avoid bending resonance of the front face.

In general, the amplitude of the displacement of the front face of such a transducer varies in inverse proportion to the effective cross section of the rod; therefore, as the cross section is decreased, the acoustic output should increase. The device would act as a stepped-horn transducer.

In version B, many small axial holes would be drilled in the rod from the front face to the zero-displacement node. A thin plate would cover the front face. The holes would reduce the flux of heat to less than one-tenth that of a solid rod. Again, the acoustic output would increase with the decrease in the effective cross section. Version B would also act as a stepped-horn transducer.

In version C, holes would be drilled perpendicular to the axis of the rod, orthogonal to each other in alternating layers. To maintain adequate dynamic strength, the number of holes per layer would be decreased toward the zero-displacement node. This would reduce the effective cross section exponentially toward the front end, producing the amplification characteristic of an exponential-horn transducer. A further advantage of the clear transverse holes is that they could be used as channels for cooling gas, which would help to keep the piezoelectric disks at a safe temperature without interfering with the radiated sound field.

In version D, the cross section for thermal conduction would be reduced, not by holes in the transducer, but by interposing a porous barrier between the furnace levitation chamber and the front face. The pores would be large enough to carry ade-



A Conventional Solid-Rod Transducer Contrasts with reduced cross-section version (A through C) and a porous-heat-barrier version (D). All four new concepts are intended to reduce the flow of heat to the transducer, both to protect its piezoelectric driving elements and to increase the efficiency to the furnace.

quate acoustic energy into the chamber and would be inclined at various angles to minimize the transfer of heat to the transducer. This version would be less acoustically efficient but more thermally efficient.

This work was done by Ernst G. Lierke, Emily W. Leung, and Balakrishna T. Bhat of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17620/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Mixed-Gas Sorption Joule–Thomson Refrigerator

Features would include relative simplicity, less required power, and no vibration.

A proposed mixed-gas sorption Joule–Thomson refrigerator would provide cooling down to a temperature of 70 K. A typical prior Joule–Thomson refrigerator included multiple stages of chemisorption and/or physisorption, each containing a single gas. The proposed mixed-gas Joule–Thomson refrigerator would include only one stage and no mechanical compressor. Thus, the new refrigerator would be simpler, would operate without vibrating, and would consume less power in producing the same amount of cooling.

The concept of using a single stage and mixed gases to obtain the amount and degree of cooling that would otherwise require multiple stages of single-gas sorption and Joule–Thomson expansion is based on prior research in the enhanced Joule–Thomson effect in some dual-gas mixtures. For example, as described in a British patent published in 1973, the addition of hydrocarbons to nitrogen increases the Joule–Thomson cooling tenfold.

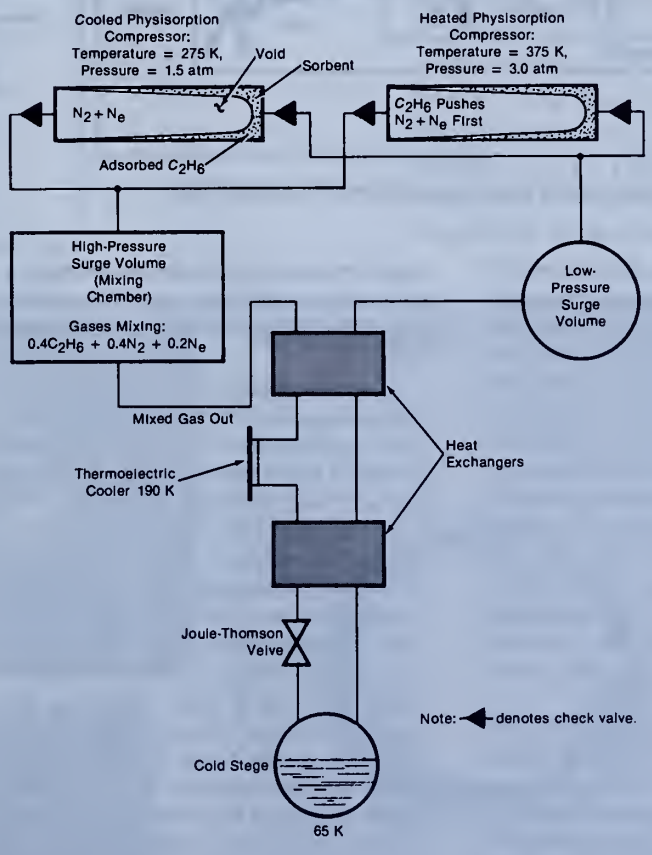
In the proposed refrigerator, the working fluid — a mixture of propane, methane, ethane, nitrogen, and neon gases — would be circulated by two physisorption compressors that would be alternately heated and cooled between temperatures of 275 and 500 K. At the stage of operation illustrated in the figure, the hydrocarbon gases would be preferentially adsorbed from the gas mixture entering the left physisorption compressor, while the less-adsorbable nitrogen and neon would mostly pass through the sorbent to the void space in this unit. At the same time, heating would drive the hydrocarbon gases out of the sorbent in the right physisorption compressor. The hydrocarbon gases would push the nitrogen and neon, and then some of itself out of the void space in this unit and into a surge-volume chamber, in which the gases would be remixed.

From the surge volume, the mixture would flow through two heat exchangers, in which it would be cooled by the gas mixture returning from the cold stage. Between the two heat exchangers, the gas mixture flowing toward the cold stage would be cooled further by a thermoelectric device, causing the hydrocarbon gases to begin to liquefy. The mixture would then pass through the Joule–Thomson valve, causing further cooling and liquefaction. The boiling of the liquid would provide cooling at 70 K in the cold stage, and the evaporated mixture would return through the heat exchangers and a low-pressure surge volume to the cooler sorption compressor. The combination of fluids remains as a liquid even though the hydrocarbons would individually freeze out if not in the mixture.

The same sorption principle of operation may be applicable in a compressor that would chemisorb oxygen or hydrogen from a mixture with helium, neon, and/or other nonreactive gases.

This work was done by Jack A. Jones, S. Walter Petrick, and Steven Bard of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17569/TN.


Cooled Physisorption Compressor: Temperature = 275 K, Pressure = 1.5 atm
Void
Sorbent
Heated Physisorption Compressor: Temperature = 375 K, Pressure = 3.0 atm
$N_2 + N_e$
C_2H_6 Pushes $N_2 + N_e$ First
Adsorbed C_2H_6
High-Pressure Surge Volume (Mixing Chember)
Gases Mixing: $0.4C_2H_6 + 0.4N_2 + 0.2N_e$
Low-Pressure Surge Volume
Mixed Gas Out
Heat Exchangers
Thermoelectric Cooler 190 K
Joule-Thomson Veive
Note: ← denotes check valve.
Cold Stege
65 K

The **Mixed-Gas Joule-Thomson Refrigerator** would have only one two-compressor stage of physisorption and no mechanical compressor.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

System Would Keep Telescope Reflector Segments Aligned

Actuators would adjust segments in response to sensed positions.

A proposed actuation system would maintain the alignments of the reflector segments of a large telescope. Although the system is intended for use on an orbiting 18.4-m Cassegrain telescope reflector composed of 90 2-m hexagonal mirror segments, the system concept is also applicable to such large segmented space-based reflectors as those used in communication and in the collection of solar energy.

Mirror fabrication technology and launch vehicle cargo volume limit the size of a single mirror. Constructing an array of mirror segments in space is one means of achieving a large-diameter reflector. The task then becomes one of maintaining the correct optical figure and alignment of the reflector array in the face of both support-truss vibration (caused by reaction wheels, solar array drives, and other mechanisms on the telescope) and thermal distortions (e.g., those caused by temperature change as the telescope goes in and out of the Earth's shadow).

The proposed system, shown in Figure 1, would perform this task. Sensors would measure the positions and orientations of the segments. A figure-control computer would calculate the orientation and figure of the overall reflector surface from the sensor data. Responding to the computer output, the servocontroller for each actuator would correct the piston (displacement along the optical axis of the segment) and tilt errors of each segment. No attempt would be made to correct for errors of translation perpendicular to, or rotation about, the optical axis of the telescope, and the segments would be restrained against motion in these degrees of freedom.

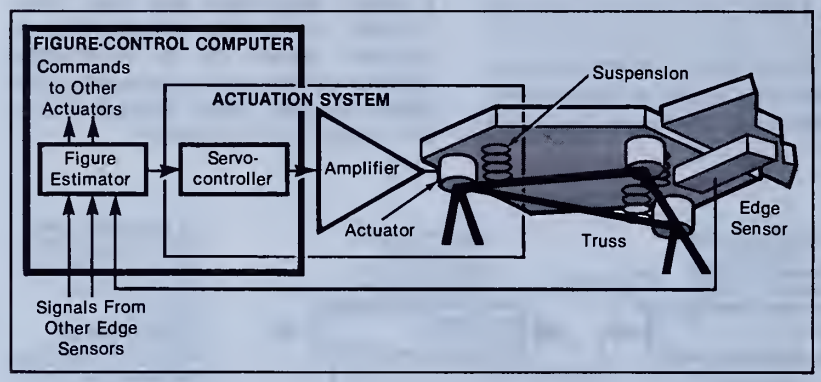

Figure 1. **The Control System** would adjust the alignment of a single mirror panel in the array.

The piston displacement and the two tilt angles of each panel would be measured relative to those of the adjacent panels by a system of edge sensors. The edge sensor for each pair of adjacent reflector segments would include four three-wavelength interferometers that would measure the distances between a sensor block behind the segments and two retroreflectors on the back of each segment.

Three electrodynamic (voice coil) actuators would correct the piston and tilt error of each segment. The actuators would be part of a suspension subsystem, called the Unit Cell, as shown in Figure 2. The mirror segment and actuators would be attached to a subplane rather than directly to the telescope support truss, so that the suspension could be assembled, aligned, and calibrated before launch. The Unit Cell is designed so that it can easily be attached to the truss during space assembly. The suspension would consist of three struts, as shown in the figure. The suspension would act as a kinematic attachment between the panel and subplane, allowing motion only in the controlled degrees of freedom as well as allowing independent thermal growth of the panel and subplane. The suspension would also act as a mechanical low-pass filter to isolate the panel from truss vibrations. The subplane would have its own kinematic attachment to the truss, consisting of three linear flexures that point toward the center of the cell. This would ensure that the subplane is not structurally redundant with the truss. The attachment would be stiff to rigid body truss motion but would allow for initial misalignments and independent thermal growth of the two structures without distortion.

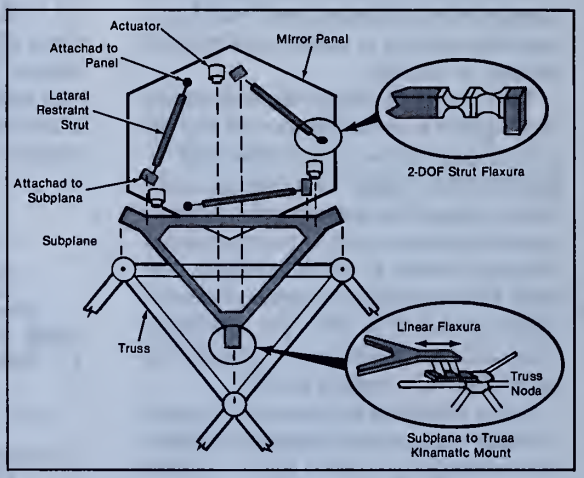

Figure 2. This **Exploded View** illustrates the Unit Cell, which is a suspension subsystem. A breadboard of this subsystem has been built and tested.

A breadboard of the Unit Cell has been built and tested to demonstrate the position control and disturbance isolation capabilities of the actuation system.

This work was done by Edward Mettler, Daniel B. Eldred, Hugh C. Briggs, Michael L. Agronin, and Taras Kiceniuk of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17903/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Fiber-Optic Hydrophone Developed

Fiber-optic sensors have been demonstrating the capability of measuring most physical quantities with potentially high levels of sensitivity and precision. A planar fiber-optic, acoustic sensor that provides the Navy with a low flow-noise hydrophone has been under joint development by the David Taylor Research Center (DTRC), Carderock, Maryland, and the Naval Research Laboratory (NRL), Washington, D.C. The same hydrohone, because of its low flow-noise characteristics, is also ideally suited for determining the low wave-number pressure components of fluctuating pressures underneath a turbulent boundary layer (TBL). When the wave-number characteristics of the TBL pressure fluctuations match well with the wave-number responses of the structure of an underwater vehicle, the structure becomes easily excited and the resulting vibration can be a noise source. Therefore, it is necessary to have an accurate description of the wall pressure fluctuations underneath a TBL in studying flow/structure interaction problems. The same pressure fluctuations also become unwanted noises (flow noise), which affect the hydrophone's ability to measure acoustic energy.

A photograph of the planar fiber-optic hydrophone is shown in Figure 2. Unique features of the current fiber-optic hydrophone design are its insensitivity to vibration and acoustical transparency. The insensitivity to vibration may allow direct mounting of the hydrophone on a

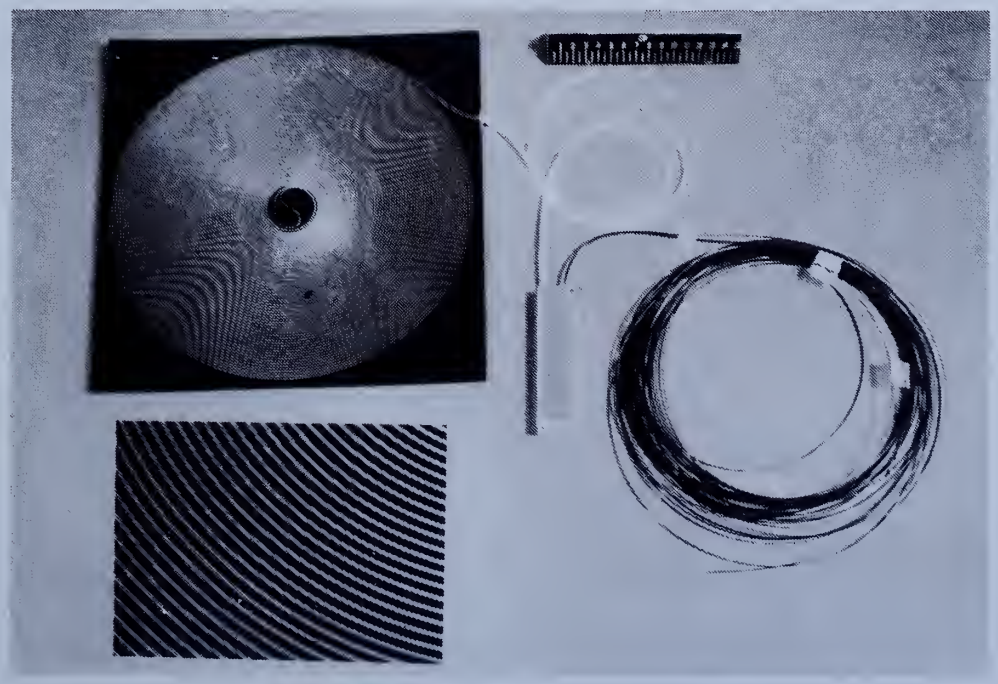


Figure 2. Planar fiber-optic hydrophone

structure. The acoustical transparency can provide array designer with additional signal processing advantages by constructing arrays with multiple layers of the hydrophone. The acoustic sensitivity is the best among all reported planar fiber-optic sensors. Experiments also showed that the fiber-optic hydrophone was better at rejecting vibration responses than a DVF_2 hydrophone of similar geometry.

The acoustic transparency of the hydrophone was also experimentally verified through insertion loss measurements.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 160402/TN

Environmental Science & Technology

0803 Highly Accurate Sensor for Soils

0804 Sensing Chemicals

Department of Energy

Technology Application

Pacific Northwest Laboratory

Highly Accurate Sensor for Soils

A newly developed sensor which provides highly accurate readings of water and liquid contaminant levels in soil and other porous materials has been licensed to a Seattle firm by the Pacific Northwest Laboratory.

The electro-optic liquid sensor is more accurate, simpler to use and less expensive than current sensors.

Technology for the sensor was licensed to Cambria Corporation, a Seattle-based electronics and industrial control company specializing in the detection of contaminants in soil. The licensing agreement includes exclusive territorial rights for applications involving detection of leaks in oil pipelines and fuel storage tanks.

According to the corporation's president, Dr. Douglas Johnson, Cambria also will continue the technological development to produce a sensor with the ability to detect a broader range of organic liquids in soil.

"We saw potential in expanding the existing technology to develop a broad-based sensor which could be instrumental in the detection of contaminants in ground water," Johnson said. "Ground water constitutes 80 percent of our supply of drinking water, so the accurate detection of contaminants is extremely important to all of us in the United States. Through the application of this technology, our goal is to play a key role in the preservation and improvement of this country's ground water supply."

Originally, the sensor was produced under DOE's Office of Energy Research, Subsurface Science Program, which was aimed at studying the movements of organic fluids in the subsurface environment and methods to reduce or repair their ecological effects. The sensor has the ability to read liquid levels in a variety of porous materials such as soil, sand and cement and may be used in several applications such as an irrigation meter for farmers or a monitoring device for remediation measures.

The sensor consists of an optical switch containing a solid-state infrared light emitting device that is joined to a porous disk made of ceramic, fritted glass, Teflon™, or various carbon-based materials. Which material the disk is constructed from is dependent on the type of liquid to be detected. The disk is placed into the soil where liquid, if present, is absorbed. Light transmitted through the disk is measured and is proportionate to the amount of water or organic liquid absorbed into the pores. The amount of liquid in the disk can be related to the amount of liquid in the surrounding soil. The disk remains in the soil the entire time the measurement occurs and can be left in the ground for repeated measurements.

For further information, contact Marv Clement, (509) 375-2789. #

Sandia National Laboratory

Sensing Chemicals

Researchers at Sandia National Laboratories are developing a portable acoustic wave (AW) sensor system to monitor the chlorinated hydrocarbon (CHC) emissions in industrial exhausts and CHC concentrations in an industrial workplace.

Real-time information about chemical species present in an industrial environment can help engineers adjust their processes to reduce wastes and emissions and to improve product quality or yield. In addition, these monitors can be used to verify compliance with environmental regulations for chemical emissions and to prevent worker exposure to unsafe chemicals. For such applications, Sandia has designed chemical monitors using coated AW devices.

AW devices are simple, rugged sensors consisting of a quartz substrate and two patterned gold electrodes to launch and detect acoustic waves. The device is covered with a coating that absorbs certain chemicals present in a particular environment. As an acoustic wave travels from one electrode to the other, the presence of chemicals absorbed by the coating changes the wave's properties. Measurement of the wave's alteration can be used to indicate the identity and concentration of specific chemical species in the environment.

By using coatings with selective absorption properties, investigators are developing sensors that can detect specific chemical species for both gas-phase and liquid-phase environments.

In general, these coatings are durable, oxide coatings that are chemically modified to provide the absorption characteristics needed. For example, one area of study is to develop coatings that selectively absorb ionic species from solution, for use in applications such as monitoring electroplating operation processes and monitoring waste streams for toxic species such as chromium, cadmium, or lead.

Alternatively, polymer coatings, which adsorb a wide variety of chemicals, have been found to be ideally suited for monitoring the highly regulated and ozone-depleting chlorinated hydrocarbons. Simultaneous measurement of changes in the acoustic wave's velocity and energy can be used to identify a chemical species and its concentration. Researchers are now developing a portable AW sensor system using polymer coatings for monitoring CHC emissions in industrial exhausts and for monitoring CHC concentrations in an industrial workplace.

Finally, acoustic wave devices are being used to characterize various properties of thin (0.1 to 10 micrometers) films. For example, surface areas and pore size distributions of porous coatings, diffusion rates and viscoelastic properties of polymer coatings, and coating corrosion or chemical alteration can be directly characterized using AW devices.

FOR ADDITIONAL INFORMATION: For more information, call Greg Frye, (505)844-0787, or Steve Martin, (505)844-9823, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

Manufacturing, Machinery & Tools

0805 Carbon-Carbon Components for Expandable Turbine Engines

0806 Linear Friction Welding Study

0807 Machining Center Standard Will Improve Manufacturing

0808 RTEC Enhances Machine-Tool Accuracy

0809 Casting of Multilayer Ceramic Tapes—High-density ceramic tapes are made by centrifugal casting.

0810 Compact Pinch Welder—An air-driven handtool makes precise spot welds. (Licensing Opportunity)

0811 Spot-Welding Gun is Easy to Use—Air pressure and vacuum, rather than the technician, provide the welding force. (Licensing Opportunity)

0812 Plasma-Arc Torch for Welding Ducts in Place—Modifications enhance maneuverability in confined spaces.

Testing & Instrumentation

0813 Penetrant-Indication-Measuring Compass—Fluorescent tips are easily viewed against the background.

0814 Verifying X-Radiographs with Computed Tomographs—A nondestructive technique gives added confidence in inspection. (Licensing Opportunity)

Carbon-Carbon Components for Expandable Turbine Engines

The need for improved performance tactical and strategic missiles is driving new weapon system design and development. Propulsion system performance improvement offers the most potential for achieving enhanced weapon system capability, but also has proven to be a major barrier toward achieving those goals.

Historically, engine component designs were generally limited by available material capability. Through the Integrated High Performance Turbine Engine Technology (IHPTET) initiative, advanced material concepts are being combined with innovative structural designs to achieve major gains in engine performance, efficiency and structural integrity.

The demonstrated design concepts evolving from the Joint Expendable Turbine Engine Concepts (JETEC) program (the expendable engine subset of the IHPTET initiative) will provide a major source of candidates. Improved manufacturing processes demonstrated for proven expendable engine designs will provide a significant performance increase and cost reduction potential for a wide range of tactical and strategic missile applications.

Of particular interest are coated, inhibited carbon-carbon composites. The high specific strength at high temperature offered by this material combination should yield component capabilities and associated engine performance gains that will prove attractive to the missile systems design community.

The basic program objective is to manufacture affordable carbon-carbon components for expendable turbine engine applications. Specifically the JETEC program will address load bearing, high temperature components that have direct technology transfer/application potential to a company's expendable engine product line. An additional program objective is to establish and validate an industrial base capability for manufacturing the expendable engine components.

This effort requires the demonstration and evaluation of carbon-carbon component parts; for example, the combustor, turbine, vanes, and exit nozzle parts fabrication technology in expendable engine application. Based on the design and the affordability and performance requirements established, this effort will: 1) analyze the carbon-carbon materials supplier and component supplier segment of the industrial base to meet these established engine requirements, 2) evaluate/select the fiber placement process, consolidation, densification, coating, and machining processes for affordable component generation, 3) address necessary refinements to the selected processes to meet established engine application requirement conditions and cost goals, 4) fabricate a number of the selected component parts to validate the processes (singularly and/or in combination), and 5) evaluate the manufactured components in a comprehensive set of coupon, component and full-scale engine tests.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Vincenzo Dibenedetto, Air Force Manufacturing Technology Program, ATTN: AFWAL/WL/MTPN, Wright Patterson AFB, OH 45433-6533; (513)255-1361.

National Center for Excellence in Metalworking Technology (NCEMT)

Navy Technology Fact Sheet

Linear Friction Welding Study

The National Center for Excellence in Metalworking Technology (NCEMT) has undertaken a program to assess the capabilities of a newly developed welding process for joining aerospace materials. Linear Friction Welding was developed by the Welding Institute (TWI) of Abington, U.K. Another closely related process, Linear Friction Surfacing, will also be studied.

The program consists of welding and surfacing several different materials combinations by the Linear Friction Process at TWI. The NCEMT will then evaluate the process by performing tensile tests, Charpy impact tests, and SEM analysis of the resulting weldments. Following is a list of the materials combinations to be welded and surfaced as part of this program:

1. L-605/MAR-M-302
2. Stellite-12 Cobalt/IN100
3. IN738/IN738
4. Waspalloy/Waspalloy
5. 6-4 Titanium/6-4 Titanium
6. Rene' 80/Rene' 80
7. PWA 1484 Single Crystal/PWA 1484
8. AM355 Stainless Steel/AM355
9. Rene' 80 (DS)/Rene' 80 (DS)

Material combinations 1 through 9 will be Linear Friction Welded, and material combinations 1 and 2 will also be Linear Friction Surfaced. These material combinations support jet engine repair applications as identified by the Naval Air Depot, Cherry Point, North Carolina.

This program is a short term feasibility study to be completed by October, 1991.

Should this process prove viable, NCEMT and the Navy MANTECH Office will explore further opportunities for implementation of this technology at other Naval facilities.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Mr. Rich Green, Welding Engineer, National Center for Excellence in Metalworking Technology, 1450 Scalp Avenue, Johnstown, PA 15904; (814) 269-2557.

Machining Center Standard Will Improve Manufacturing

A new American Society of Mechanical Engineers (ASME) standard will soon provide machine tool builders and users with a uniform method to evaluate performance of metal-cutting machining centers. The standard, "Methods for Performance Evaluation of Computer Numerically Controlled Machining Centers," is designated ANSI/ASME B5.54 (Draft). It will benefit both purchasers and manufacturers of machining centers since it will eliminate the need to write custom specifications for acquiring machinery. The standardization of testing criteria will allow users to more accurately compare capabilities of different machines.

Some of the innovative machining center performance measures that B5.54 covers are: contouring performance using a precision disk, contouring performance using laser diagonal method, machine compliance, spindle error analysis, cutting-performance tests for detecting susceptibility to chatter, and evaluation of the machining center as an inspection device.

The new standard is based on research conducted at NIST, Lawrence Livermore National Laboratory, the University of North Carolina (Charlotte), and the University of Florida (Gainesville). The Navy and the National Center for Manufacturing Sciences partially funded the work. Formal approval of the standard should be completed by May 1991.

Workshops, demonstrations, and video tapes will be used to introduce users and suppliers of machining centers to the standard. The B5.54

A Three Axis Vertical Machining Center Being Measured Using Laser Interferometry

subcommittee welcomes help with this educational process from industry, government agencies, trade and professional associations. Organizations willing to loan or donate equipment, instruments, and tools, sponsor video tapes, provide facilities for workshops and demonstrations, and/or financially support workshops, should contact the subcommittee chairman, Denver Lovett.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Denver Lovett, Shops Building, Room 136, AMRF Project, National Institute of Standards and Technology, Gaithersburg, MD 20899; (301)975-3503.

Navy Manufacturing Technology

Automated Manufacturing Research Facility

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

RTEC Enhances Machine-Tool Accuracy

AMRF engineers have developed a practical method for applying software correction to machine tools without "getting inside" the machine tool controller. This method, known as the Real-Time Error Corrector (RTEC), modifies the tool path during cutting based on predicted machine-tool systematic errors (such as geometric and thermally induced errors). The result is that the machine tool produces higher accuracy parts, even during much of its thermal warm-up period

Correction of the tool path, based on the prediction of the geometric and thermal errors, has previously been achieved by modifying the hardware and/or software of the machine-tool CNC controller. However, this type of modification requires detailed knowledge of the existing controller software and hardware. This requirement has been the major obstacle to implementing real-time error compensation of machine tools. NIST developed the Real-Time Error Corrector (RTEC) to eliminate the machine tool controller interfacing problem.

The RTEC is inserted between the machine-tool controller and the machine-tool's encoder-type position feedback devices. The RTEC is capable of modifying the tool path without any knowledge about the machine-tool controller's design.

The RTEC consists of an 8-bit microcomputer chip and a quadrature decoder/counter chip. The position feedback signals generated by the encoder are fed to the decoder chip, which translates this information into servo counts and sends them to the microcomputer. The microcomputer then converts the servo counts into axis position and sends this to a PC-type computer. The amount of correction required is determined by the PC and sent back to the RTEC. RTEC, in turn, generates new feedback pulses by adding or subtracting from the original encoder pulses and sends them to the machine controller. For positive axis movements, if there are additional pulses, the machine stops earlier than the programmed nominal position. If pulses are subtracted, the machine moves further than the target position.

The current version of RTEC can modify the tool path at slide traverse rates of up to 30 inches per minute. An inherent restriction of the RTEC is that the dimensional resolution of the modification is four-times coarser than the resolution of the machine tool. Further study is needed to determine if this is a serious practical limitation. The successful operation of the RTEC, while cutting a part, has been recently demonstrated. The RTEC is part of the Quality in Automation (QIA) control architecture.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Denver Lovett, Shops Building, Room 136, AMRF Project, National Institute of Standards and Technology, Gaithersburg, MD 20899; (301)975-3503.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

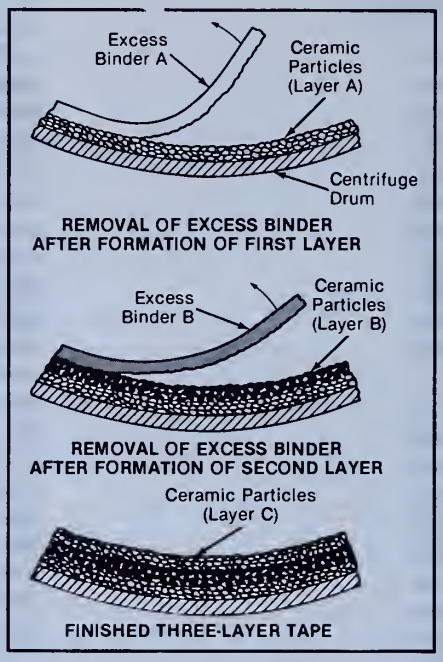
Casting of Multilayer Ceramic Tapes

High-density ceramic tapes are made by centrifugal casting.

A procedure for casting thin, multilayer ceramic membranes, commonly called tapes, involves centrifugal casting at accelerations of 1,800 to 2,000 times the normal gravitational acceleration. These tapes are used in capacitors, fuel cells, and electrolytic separation of oxygen from the air.

The layers of a tape are cast one at a time on top of any previous layer or layers (see figure). Each layer is cast from a slurry of ground ceramic suspended in a mixture of solvents, binders, and other components. The high casting force in the centrifuge produces very uniform and tightly packed cast ceramic layers. The flexible tapes thus produced are subsequently fired in a kiln to remove solvents and other impurities. The resulting hard multilayer ceramic "sandwiches" can contain electrode and insulating layers.

Having a density lower than that of the ceramic, the excess solvent/binder floats to the surface during centrifugation. Because only the minimum amount of solvent/binder necessary to fill the interstices remains in the ceramic layer, the strength of the bonds in the ceramic layer is very high. After curing, the film of excess binder on top of the ceramic layer can be peeled off easily without disturbing the ceramic layer beneath.


Excess Binder A
Ceramic Particles (Layer A)
Centrifuge Drum
REMOVAL OF EXCESS BINDER AFTER FORMATION OF FIRST LAYER
Excess Binder B
Ceramic Particles (Layer B)
REMOVAL OF EXCESS BINDER AFTER FORMATION OF SECOND LAYER
Ceramic Particles (Layer C)
FINISHED THREE-LAYER TAPE

A Three-Layer Ceramic Tape is cast in a centrifuge. After a ceramic layer is cast and cured, the film of excess binder is peeled off before casting the next layer.

The next layer can then be cast on top of the exposed layer, provided that it is made with a different solvent/binder solution that does not attack the exposed layer. Even if several layers are to be cast, only two solvent/binder mixtures, used in alternation, should be required, because only the immediately preceding layer is exposed and therefore likely to be affected by the solvent in the next layer.

To enhance ease of handling and to provide easier removal of the tapes from the centrifuge drum, a protective coating layer can be deposited and cured before casting the first ceramic layer. A similar layer can also be added after casting the last ceramic layer.

This work was done by Earl R. Collina, Jr. of Caltech for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Compact Pinch Welder

An air-driven handtool makes precise spot welds.

A spot welder is designed for bonding insulated metal strips together. The welder is compact, measuring only about 33.5 cm in its largest linear dimension (see figure).

The hand-held unit is a welding gun that uses compressed air to drive its opposed electrodes into the workpiece. It provides a higher, more repeatable clamping force than does a manually driven gun and thus produces weld joints of higher quality. It is light in weight and therefore can be positioned precisely by the operator.

Holding the gun by its handles, the operator places the electrodes at the spot-weld site and presses the trigger on the handle. Partially depressing the trigger activates the pneumatic cylinder, thereby clamping the electrodes on the workplace. Fully depressing the trigger closes the welding circuit and enables welding to take place. Releasing the trigger breaks the welding circuit and allows the pneumatic cylinder to vent, which enables the return spring to return the welding electrodes to the original position.

This work was done by Gene E. Morgan and Clark S. Thomas of Rockwell International Corp. for **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29670/TN.

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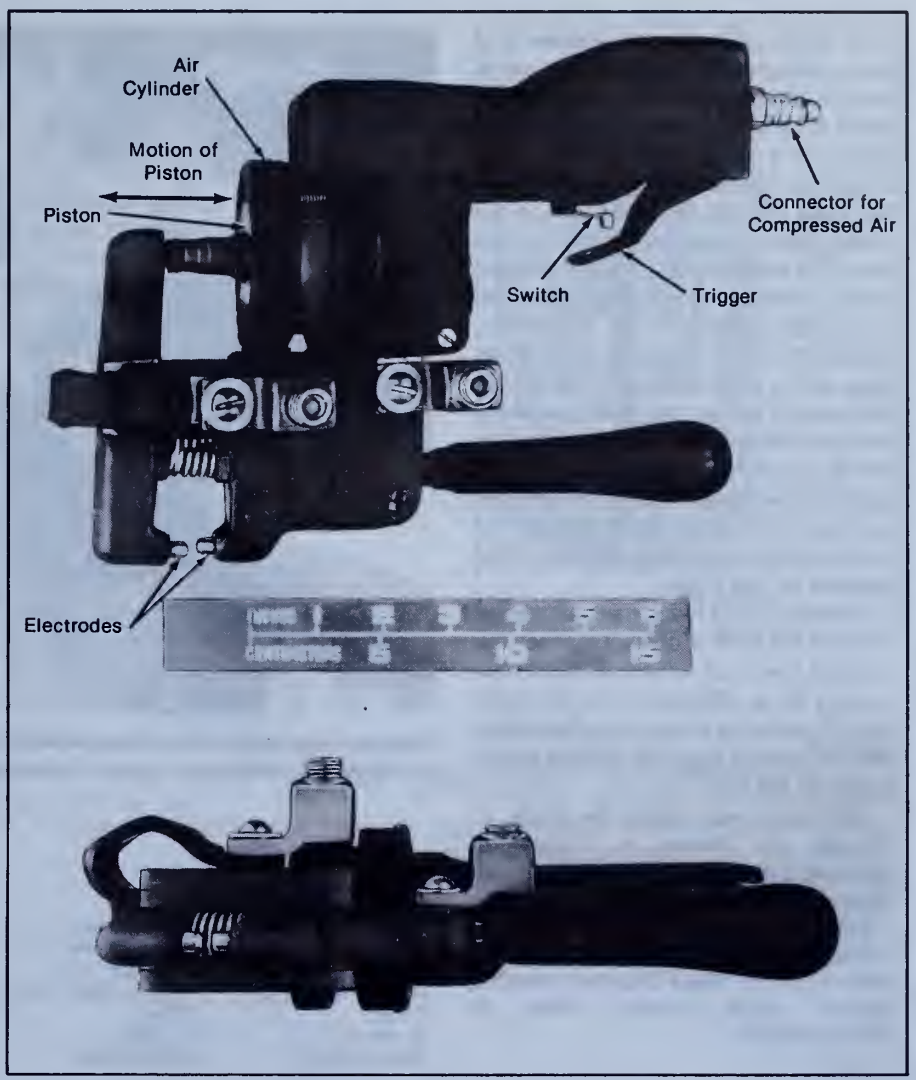

The Pinch Welder clamps electrodes on weldments with a strong, repeatable force. Compressed air is supplied through a fitting on one handle. A small switch on the same handle starts the welding process when the operator presses it with the trigger.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Spot-Welding Gun Is Easy To Use

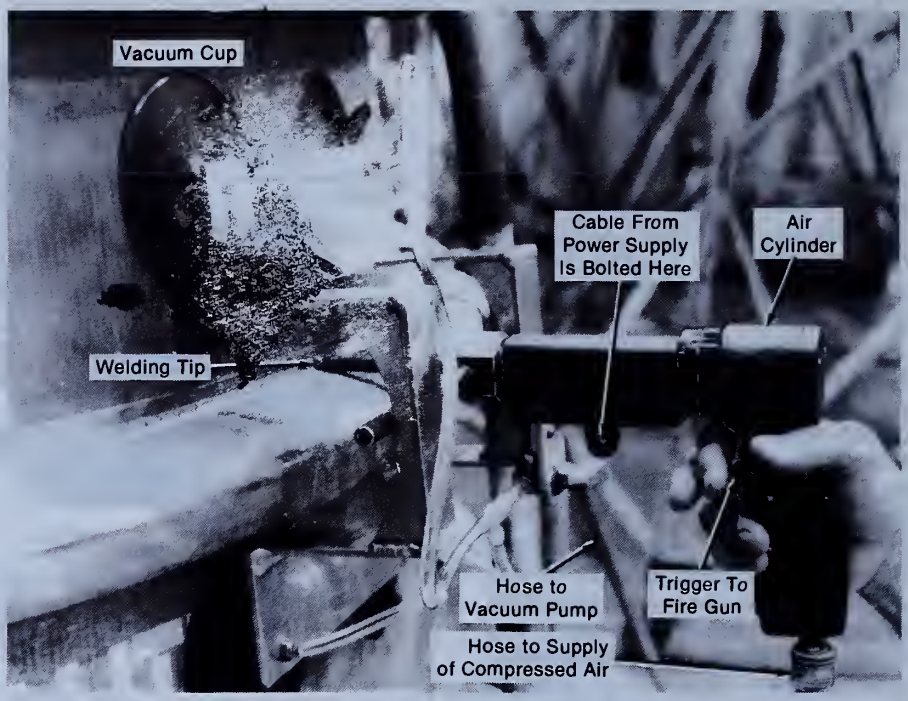
Air pressure and vacuum, rather than the technician, provide the welding force.

An electrical-resistance spot-welding gun is designed to produce more welds per unit time by decreasing the technician's effort and fatigue. The gun is connected by a hose to a supply of compressed air, and vacuum cups on a frame that holds the gun on the workpiece are connected by a hose to a vacuum pump. When the technician depresses a trigger on the handle of the gun (see figure), the air actuates a piston in an air cylinder, pressing the welding tip against the workpiece with a force of about 40 lb (178 N). The force of the atmosphere against the vacuum cups holds the tool securely when the air pressure drives the welding tip against the workpiece; the technician does not have to furnish the reaction force. The only force the technician need exert is the squeeze on the trigger.

Welding current is automatically turned on when the force of contact reaches the required level and turned off before the welding tip is withdrawn from the workpiece. A cable (not shown in the figure) carries the current from the welding power supply to the gun.

This work was done by Gene E. Morgan and Francis H. Nguyen of Rockwell International Corp. for **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29693/TN.



Vacuum Cups on the Frame Secure the Welding Gun to the workpiece while compressed air drives the welding tip against the workpiece to make a spot resistance weld.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Plasma-Arc Torch for Welding Ducts in Place

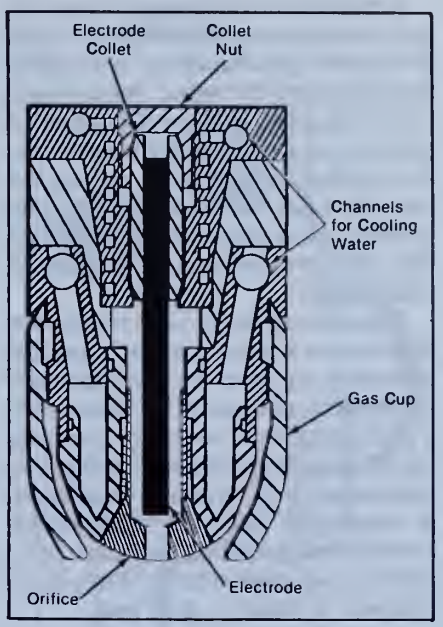
Modifications enhance maneuverability in confined spaces.

A plasma-arc-welding torch has been redesigned to make it more suitable for applications in which it must be moved in circular or other orbits about stationary cylindrical workpieces. It could be used, for example, to weld a duct that is already mounted in place for its intended use.

The improved design (see figure) preserves those elements of the original design that are critical to performance and endurance, but modifies other elements to decrease the overall size of the torch. The original torch works well where radial access is unrestricted and the torch is not moved beyond ±90° around the workpiece. The improved torch can be used where access is restricted to tightly radially confined spaces and is compatible with mechanisms that rotate it 360° around a stationary part with a circular weld joint.

The height of the torch has been reduced from about 6 in. (15.2 cm) in the original to 2.4 in. (6.1 cm) in the improved design. Whereas the fittings for cooling water were placed on the top in the original design, they are placed on the side in the improved design. Side-mounted fittings are preferable for orbital motions because they improve radial clearance, make the water hoses less vulnerable to crimping, and reduce the mechanical load on the torch. Also in the improved design, the electrode collet and collet nut are installed and removed through a hole in the top; this makes installation and removal much easier than in the original design.

This work was done by Kenneth J. Gangl of Rockwell International Corp. and Ernest Bayless and Alan Looney of **Marshall Space Flight Center.**
MFS-29701/TN



The Improved Plasma-Arc Torch is configured for compactness and maneuverability to facilitate welding of stationary ducts in confined spaces.

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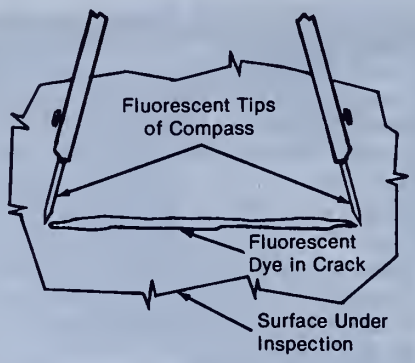
NASA Tech Brief
National Aeronautics and
Space Administration
Marshall Space Flight Center, Alabama

Penetrant-Indication-Measuring Compass

Fluorescent tips are easily viewed against the background.

A modified drafting compass is well suited to measurement of the length of a crack or the width of an area stained by the penetrant-dye-inspection method. The compass can be equipped with any of a variety of standard curved or straight pointed tips. The modification consists in coating the tips with a dye that fluoresces light pink under the same ultraviolet inspection light that causes the penetrant dye to fluoresce yellow green.

The compass can be used in locations inaccessible to a conventional fluorescent comparator; e.g., where the curved tips might be needed to reach around a corner, where a comparator might not fit. The compass can eliminate errors of optical distortion in the comparator. It can also eliminate errors of interpolation, which can be significant inasmuch as standard fluorescent comparators give linear indications only in increments of 0.030 in. (0.75 mm).



The Tips of the Compass fluoresce with one color, the penetrant dye in the crack with another color. The contrast between the colors facilitates measurement of the length of the crack.

By use of the microadjustment screw on the compass, the distance between the tips is adjusted in the customary manner until the tips point to the ends of the crack. The adjustment is easy because the pink fluorescence of the tips is easily seen against the dark background and against the yellow green fluorescence of the dye (see figure). The distance between the points is then measured with a micrometer or scale in the usual way.

If desired, the tips can be coated with plastic before coating them with fluorescent dye, to prevent scratching of the surface to be inspected. All of the components can be purchased at hardware and drafting-supply stores.

This work was done by Lloyd Schaefer of Rockwell International Corp. for **Marshall Space Flight Center.**
MFS-29643/TN.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Verifying X-Radiographs With Computed Tomographs

A nondestructive technique gives added confidence in inspection.

Ambiguous indications in radiographic inspections of metal castings can be checked by computed tomography. Fast and inexpensive conventional x-ray inspection is used to make a film image of the overall casting, and slower, more costly computed tomography is used to reinspect the relatively few parts of the casting that present possible diffraction patterns or other difficult-to-interpret features.

The method has been effective in resolving ambiguities in radiographs of turbine blades. A nondestructive technique, computed tomography provides the same information as does metallurgical sectioning.

In computed tomography, x or γ rays penetrate a casting in a fan-shaped pattern. An array of detectors on the opposite side collects the energy that passes through the casting (see Figure 1). A computer analyzes the detector signals and constructs a density map of the casting at various cross sections on a video monitor.

For example, a conventional radiograph may contain a "ghost" indication, caused by grain diffraction, that may be misconstrued as a flaw or may hide a real flaw (see Figure 2). A tomograph of the affected area shows whether the pattern in it is a diffraction "ghost" or representative of a real feature of the casting.

This work was done by Jagatjit Roy and Antonio G. Pascua of Rockwell International Corp. for **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29649/TN.

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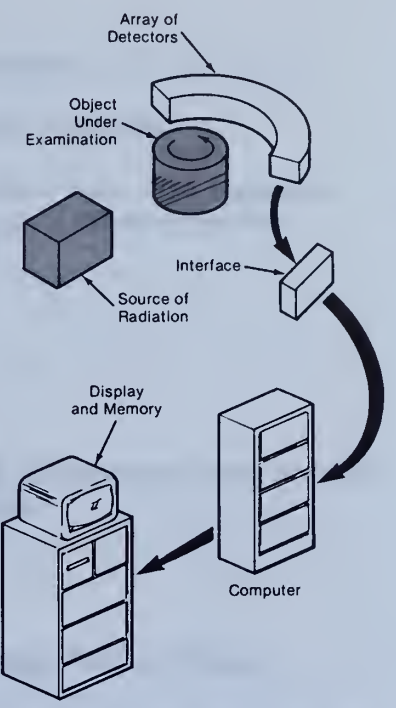

Figure 1. **X- or γ-Ray Computed Tomography** can be used to verify ambiguous indications in conventional radiographs.

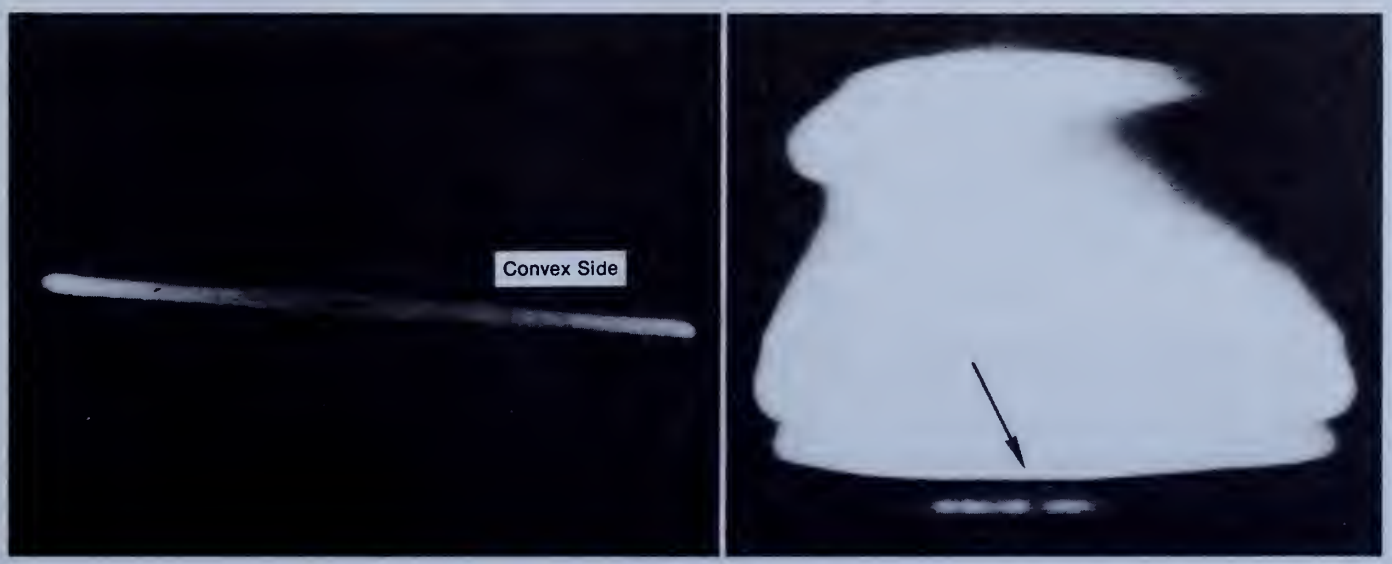

Figure 2. An **Enhanced Conventional X-Ray Image** of a turbine blade (upper photograph) contains what could be a diffraction "ghost" in the "fir tree" region just below the root of the blade. The computed tomographic image of the suspected ghost (lower photograph) shows that the ghost is, indeed, caused by grain diffraction, not by inner flaws.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Materials

0815 The Monomer of Your Choice Can Now be Modified—Enzymes Add Carbohydrates for Synthesis of Biocompatible Polymers (Licensing Opportunity)

0816 The Creep of Copper Studied

0817 Damping of Aluminum-Indium Alloys Examined

0818 PC Database on Refrigerants and Mixtures Expanded

0819 Apparatus for Chemically Treating Graphite Fibers—The apparatus dries fibers in an inert gas and is adaptable to different chemical solutions.

Testing & Instrumentation

0820 Measuring Resistivity Developed

0821 Computed Tomography for Inspection of Thermistors—Cracks invisible in conventional x-radiographs can be seen.

Other Items of Interest

0805 Carbon-Carbon Components for Expandable Turbine Engines

0809 Casting of Multilayer Ceramic Tapes—High-density ceramic tapes are made by centrifugal casting.

0813 Penetrant-Indication-Measuring Compass—Fluorescent tips are easily viewed against the background.

Applications include biocompatible materials; contact lens material; chromatographic packings: antigens, antibodies, and enzymes; membranes; affinity chromatography; affinity electrophoresis; non-nutritive sweeteners; drug delivery systems; biodegradable structural materials; semi-biodegradable structural materials; and biotechnological applications for substances that mimic cell surfaces.

Development Status: The Technology Transfer Office is currently seeking companies interested in participating in development projects for specific applications and licensing rights to this innovative procedure. Patent pending.

FOR ADDITIONAL INFORMATION: For further information, contact: Mark Owens, Jr., Technology Transfer Office, Lawrence Berkeley Laboratory, 1 Cyclotron Road, Mail Stop 90-1076, Berkeley, CA 94720; ph: (415) 486-6463, FAX: (415)486-6660.

NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

The Creep of Copper Studied

Copper is used extensively as a stabilizing material for superconducting magnets and as a conductor in high-field, cryogenic magnets. Operating such magnets puts the conductor under intense pressure for extended periods of time. To assure reliable performance, users need to know the dimensional stability of the conductor. NIST researchers have made creep measurements at 295, 76, and 4 Kelvins of 99.9 percent pure, oxygen-free copper. Paper no. 9-91 describes the NIST study.

FOR ADDITIONAL INFORMATION: Available from Jo Emery, Div. 104, NIST, Boulder, Colo. 80303; (303)497-3237. Media Contact: Fred McGehan (Boulder); (303)497-3246.

NAVY
Domestic Technology Transfer Fact Sheet

Damping of Aluminum-Indium Alloys Examined

The David Taylor Research Center (DTRC), Carderock, Maryland, and the University of Michigan, have examined high damping aluminum-indium alloys. The strain amplitude dependent damping of binary aluminum-indium alloys containing nominally 0.6 to 17.3 weight percent indium was studied. A dynamic mechanical analyzer was used to measure the damping capacity of these materials. Pure aluminum (99.99%) exhibited strain dependent damping at strain values as low as 70 microstrain. The addition of 0.6 weight percent indium reduced the strain independent damping by a factor of 2, but the strain dependent damping was equivalent to that of pure aluminum.

Binary aluminum-indium alloys containing 4, 8, 12, and 16 weight percent indium exhibited a general increase in loss factor with increasing indium content; however, the strain dependent damping was no greater than that of the pure aluminum sample. No significant increase in damping was observed when the binary alloys were tested at temperatures above the melting point of indium. Two damping peaks were observed near the eutectic melting point when tested at 10 Hz, and differential scanning calorimetry verified both of these peaks as due to the melting of the indium inclusions. It was concluded that the higher temperature damping peak was associated with smaller indium inclusions and that the damping peaks were related to the solute segregation associated with the binary eutectic reaction.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 160303/TN

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

PC Database on Refrigerants and Mixtures Expanded

Three refrigerant materials, R115, R125, and RC270, have been added to the NIST Thermodynamic Properties of Refrigerants and Refrigerant Mixture Database (REFPROP). The database is a personal computer (PC) software package for producing tables of the thermodynamic properties of 18 pure refrigerants, including the ethane-based compounds, and 24 of their mixtures. The software has been expanded to permit calculations of mixtures with up to five components. Some of these materials are possible replacements for environmentally unacceptable refrigerants. Users may also consider other mixtures of the 18 refrigerants.

FOR ADDITIONAL INFORMATION: Designed for any AT- or XT-Class PC where it occupies 512 kilobytes, NIST Standard Reference Database 23, REFPROP, Version 2.0 is available for $340 from the Standard Reference Data Program, A320 Physics Bldg., NIST, Gaithersburg, Md. 20899; (301)975-2208, FAX: (301)926-0416. Users of Version 1.0 may upgrade for $90.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

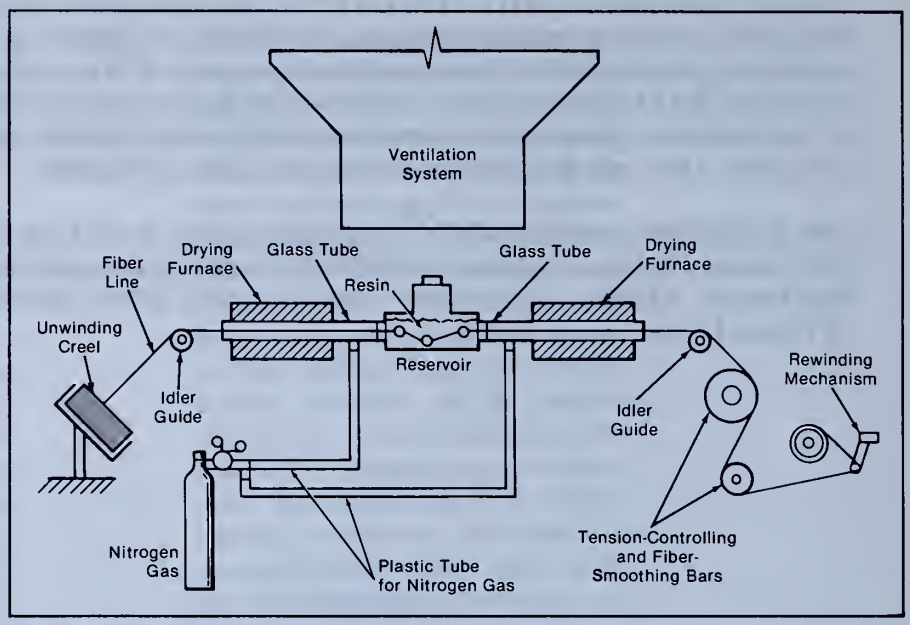
Apparatus for Chemically Treating Graphite Fibers

The apparatus dries fibers in an inert gas and is adaptable to different chemical solutions.

A new apparatus for the chemical treatment of graphite-fiber tow has been developed. The apparatus applies chemical solutions to commercially purchased unsized fibers or in-house-made fibers, to improve the following: handling of fibers, interface bonding of fiber to resin matrix during prepreg fabrication, and interface bonding in laminates during molding process. The apparatus is ideally suited for research and development of prototype, tailor-made low-solid-content solutions.

Standard units used by manufacturers to apply sizings to fibers are not designed for research and development and do not provide for predrying and postdrying in inert gases. They are also not easily adaptable to different chemical solutions. The new apparatus was designed for all thermoplastics and thermoset resin solutions to be used with graphite-fiber tow consisting of 3,000 to 12,000 filaments per tow, but it will accommodate other solutions, other numbers of filaments, and other types of fibers.

The apparatus is illustrated in the figure. A spool of unsized graphite fiber is attached to an unwinding creel and guided to a glass tube that runs through a furnace. The furnace is used to remove any moisture that may be on the fiber and to prepare the surface of the fiber for the application of resin. The fiber runs through a reservoir of resin, and after leaving the reservoir, it enters a second furnace, which removes the solvent picked up in the reservoir. The fiber is next run over a round bar 12 in. (30.5 cm) in diameter and under a round bar 3 in. (7.6 cm) in diameter, to control its tension and to smooth it. Nitrogen gas is run through the glass tube to prevent the fiber from picking up moisture and to maintain an inert environment, which is especially important when flammable solutions are employed. The fiber is rewound onto a bar that contains an empty cardboard core. The bar is turned with a hydraulic pump.



This **Research-and-Development Apparatus** is designed for the application of all thermoplastics and thermoset resin solutions to fibers.

This system was designed for research and development, with predrying and postdrying in inert environments. It is easily adaptable to different chemical solutions and is well suited for small-scale, prototype, tailor-made fiber systems. The system can be used to develop fiber/resin composites for aerospace, automotive, marine, and other applications.

This work was done by Clarence E. Stanfield of **Langley Research Center.**
LAR-13959/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NAVY
Domestic Technology Transfer Fact Sheet

Measuring Resistivity Developed

The Naval Surface Warfare Center (NAVSWC), Dahlgren, Virginia, has developed a method for measuring resistivity of materials ranging from metals to weakly conducting fiber-reinforced composites without recourse to calibration standards. The method is nondestructive and not hindered by the presence of a nonconducting coating. The method can be used to identify materials by their resistivity, to estimate fiber density, to evaluate radar absorbing characteristics, and to ensure adequate nondestructive inspection by eddy current methods.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 160306/TN

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

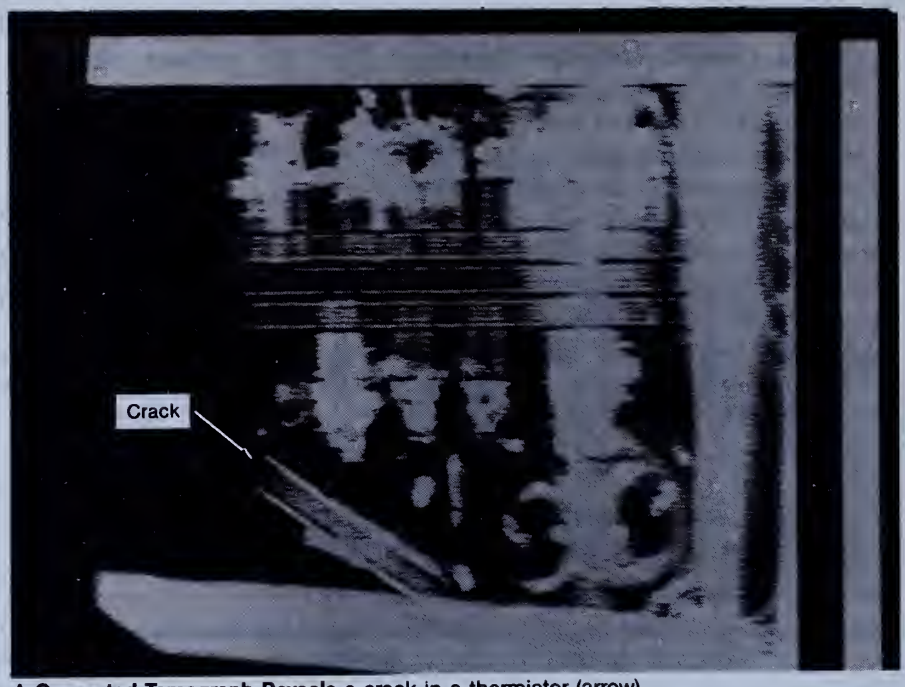
Computed Tomography for Inspection of Thermistors

Cracks invisible in conventional x-radiographs can be seen.

Computed tomography (CT) enables the identification of cracked thermistors without disassembly of equipment that contains them. CT digital radiography can resolve 65,000 shades of gray; it can be used to discern cracks in thermistors that go unnoticed by conventional radiographs and image enhancers, which offer gray scales of only 16 and 256 shades, respectively. It is unnecessary to destructively open sealed equipment to confirm or deny the supposed existence of a crack in a thermistor as the source of an electrical failure.

A CT unit is used to scan the equipment and locate the thermistors. Further scans are then made in various radial orientations perpendicular to the plane of the devices to find cracks (see figure).

This work was done by Lloyd A. Schaefer of Rockwell International Corp. for **Marshall Space Flight Center.**
MFS-29662/TN.



A **Computed Tomograph Reveals** a crack in a thermistor (arrow).

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Medicine & Biology

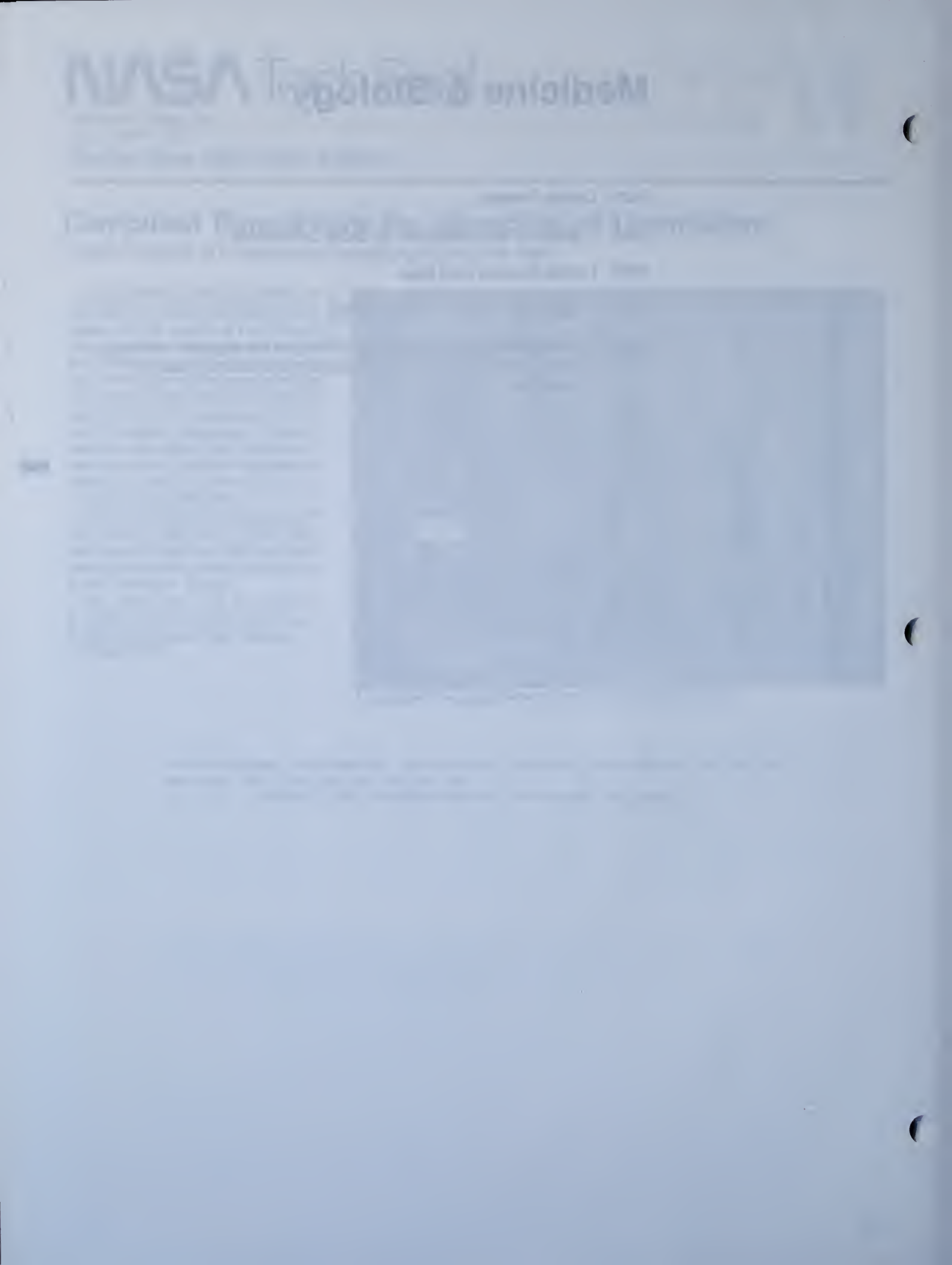
0822 Cancer Therapy

0823 Transgenic Mice Developed for Sickle Cell Anemia

0824 Human Genome Data Base

0825 Imaging and Computer Vision Center

0826 Computation of Facilitated Transport of O_2 in Hemoglobin—Unsteady transport is simulated with more-realistic mathematical models of dissociation.



Ames Laboratory

Cancer Therapy

Working with the Department of Radiation Oncology at the University of Arizona, Ames Lab metallurgists have fabricated wires that are proving effective in the treatment of malignant tumors in the brain and other parts of the body. The wires are inserted into a think plastic catheter that is then implanted in the patient's tumor. The the body. The wires are inserted into a thin plastic catheter that is then implanted in the patient's tumor. The patient is placed within an oscillating magnetic field which causes the wires, which are ferromagnetic, to heat up. Clinical studies indicate that the application of this technique, known as hyperthermia, in conjunction with radiation therapy, can be twice as effective as treatment by radiation or chemotherapy alone.

The use of inductively heated ferromagnetic wire implants is an effective means to produce hyperthermia (temperature above 40 degrees C), localized to the tumors. Just as elevated temperatures (evidenced by a fever) increase the body's ability to metabolize and destroy infectious cells, elevated temperatures in a tumor will make the cells more susceptible to damage that can be inflicted by radiation. However, physiological variables such as the region's bloodflow, and where the wires should be placed within the tumor demand a range of different treatment temperatures. Achieving the desired temperature depends on the amount of alloying element incorporated in the wire.

The Ames Laboratory Materials Preparation Center produced various alloys of wires with Curie points within a few degrees of each other. The Curie point is the critical temperature at which a material's magnetic properties change. Below this temperature, a magnetic field will cause the wire to heat up; however, above the critical temperature, the wire loses its magnetic property and cools. Thus, near the Curie point, the wire acts like a thermostat and regulates its own temperature. The wires were subjected to assay by analytical chemistry to ensure homogeneity of the composition along the length of the wire. Further research by Ames Lab scientists suggests that the size of the crystal grain boundaries may be a critical factor for obtaining consistent and reproducible results when the wire is implanted in the tumor.

In addition to work in progress at the University of Arizona, patients at the University of California's Medical Center in San Francisco, and at the City of Hope Medical Center near Los Angeles have begun receiving the hyperthermia treatment. Goals for the project include establishing a scientific base for determining whether hyperthermia, when used in conjunction with radiation or chemotherapy, is a valid cancer therapy.

For more information, contact Daniel E. Williams, (515) 294-2635.

Lawrence Berkeley Laboratory

Transgenic Mice Developed for Sickle Cell Anemia

The long-sought animal model for studying human sickle cell anemia may have been found. Scientists with the Lawrence Berkeley Laboratory have created transgenic mice whose red blood cells will sickle under the same conditions that cause red cells to sickle in humans with the disease.

Edward M. Rubin, of LBL's Cell and Molecular Biology Division, led the development of these mice which carry human genes that produce a rare but naturally-occuring form of hemoglobin with a great propensity for sickling. He says the mice should enable researchers to follow the pathophysiology of sickle cell anemia and to test experimental treatments of the disease.

Intensive studies have resulted in a detailed understanding of sickle cell anemia on both a cellular and a molecular level. However, for all that has been learned about the disease, there is still no effective treatment - a failure medical researchers attribute in part to the lack of an animal model. Mice make useful models for medical research since, in many ways, their physiology closely mimics that of humans. Currently, transgenic mice serve as animal models for a number of human diseases, including bone disorders and several forms of cancer.

Rubin and his collaborators, which include Mohandas Narla, leader of LBL's hematopoiesis research group, had created earlier strains of transgenic mice that carried human sickle cell genes. However, the blood cells of those mice did not sickle. The key to the induced "in vivo" sickling obtained with their newest strain was the use of a gene that expresses a variant of hemoglobin-S called "hemoglobin-S Antilles." Red cells containing this protein are much more likely to sickle than those containing hemoglobin-S under similar conditions.

Explains Rubin, "Sickling occurs when hemoglobin proteins precipitate out of solution during a state of deoxygenation. Hemoglobin-S Antilles gives up its oxygen much easier and will precipitate from solution much more readily than hemoglobin-S."

The alpha and beta polypeptide chains that make up the hemoglobin molecule must also interact in order for cells to sickle. Unlike his previous transgenic sickle cell mice which produced only human beta chains, Rubin's new mice contain genes for expressing both a human beta chain (S Antilles) and a human alpha chain.

Says Rubin, "As a result of the presence of human beta S Antilles and human alpha chains in mouse red cells, these cells sickle when placed in a test tube or when an animal containing them is placed in a low oxygen environment. This is similar to what occurs in humans with sickle cell anemia."

"We now have a mouse model with disease severity similar to that of an individual with a mild form of sickle cell anemia," says Rubin. "The next step is to further engineer the mouse to develop an accurate model for individuals with severe forms of this disorder."

FOR ADDITIONAL INFORMATION: Public Information Department, ATTN: Lynn Yarris, Lawrence Berkeley Laboratory, Berkeley, CA 94720; Telephone (415)486-5375.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

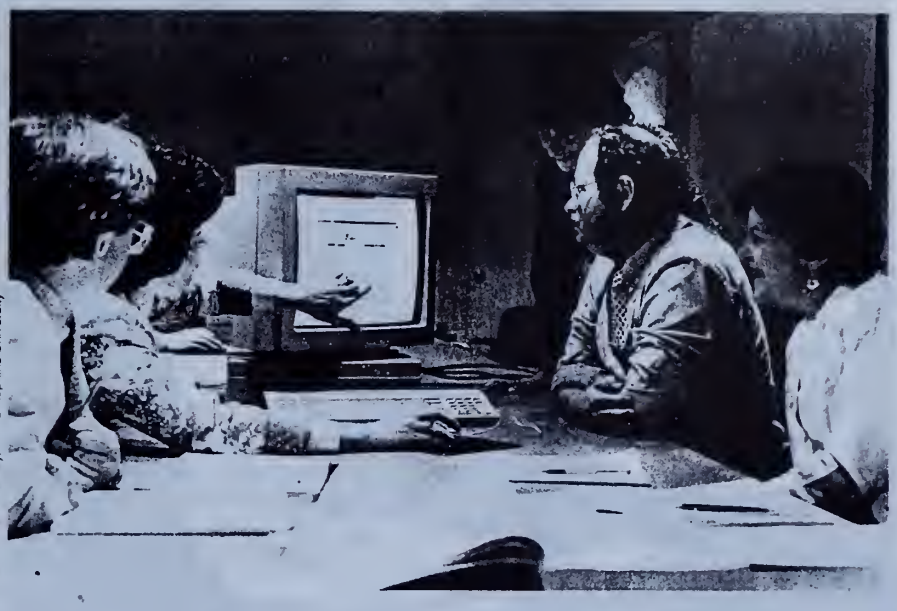
Human Genome Data Base

The Genome Data Base (GDB), located in the William H. Welch Medical Library at Johns Hopkins University in Baltimore, Maryland, is the world's only collection of all the available information on mapping and sequencing of the human genome. The GDB is an online data base that was established to allow rapid validation and entry of "the explosion of information" in this ever-advancing field and to provide ready access to this information for any researcher in the world equipped with a computer and modem.

"The Genome Data Base provides information on location of genes and DNA sequences of unknown function—really anything that can be mapped in the human genome. It has not just information on location, but also on the variations of mapped objects—for example, polymorphisms—and descriptions of DNA probes" used to study particular disease genes, says Dr. Peter L. Pearson, director of the GDB and professor of medical genetics at the university.

The GDB also incorporates the online version of Dr. Victor A. McKusick's book *Mendelian Inheritance in Man* (OMIM), a listing of disorders that are inherited in Mendelian ratio. It includes characterization of the disorders and discussions of the available literature on each one together with descriptions of all the known phenotypic markers and genes in humans. The 5,226 entries in OMIM that are currently available are updated daily under the supervision of Dr. McKusick, professor of medical genetics at the university.

The GDB, which is fully funded by the Howard Hughes Medical Institute in Bethesda, Maryland, can be accessed directly by biomedical researchers, health care providers, and science educators using Internet, the National Science Foundation's scientific computer network, or Telenet, a telephone connection system, Dr. Pearson explains. "Theoretically, anyone can contact us from anywhere in the world, using either of these two systems or the international equivalents." Approximately 2,000 users in North America, Europe, and Asia access the data base each month.



Welch Medical Library, Johns Hopkins University

Staff members of the Genome Data Base discuss with scientific editors the interface design for the GDB editorial modules for nomenclature. Pictured from left to right are Peter E. Cartwright, Howard Hughes Medical Institute (HHMI) technical consultant; Deborah Schneider, special assistant to the GDB director; Dr. Frances I. Lewitter, HHMI technical consultant; Dr. Thomas Show, GDB scientific editor at Roswell Park Memorial Institute, Buffalo, New York; and Dr. Phyllis J. McAlphine, GDB scientific editor at the University of Manitoba, Winnipeg, Canada.

"With a data base system of this sort, one of the major limitations isn't the data base itself but how good the network connections are. As time goes by, network connections keep improving; they certainly have within the last 2 years or so here in North America. But despite that, there are still certain locations—institutions and countries—where the network connections are rather poor. That depends entirely on local conditions," Dr. Pearson says.

To solve this problem, Dr. Pearson and his associates are now setting up what they call nodes of the GDB around the world. "These are clones of our data base" that include all of the information in the Baltimore data base, but the nodes are updated weekly rather than daily so that incoming information can be validated in the Baltimore system before being disseminated, he explains.

The first node has already been established in London to serve all of the United Kingdom and possibly other parts of Europe and is being run by the British Medical Research Council. "This will save people from having to get a good transatlantic connection," Dr. Pearson says.

Another node is scheduled to start up shortly in Heidelberg, Germany. "The nice thing about that one is that it is funded by the EEC [European

Economic Community], which means it will have a more European than national involvement and will be expected to serve the 17 countries collaborating in the EEC scientific program," he says. A third node is expected to start up in Japan within the year.

"Global access is important for enabling researchers everywhere to look up the information in our data base. But it is just as important to maintain and update the information, which is also done internationally," he continues.

About 60 genetics experts worldwide are editors for the GDB. They can modify existing information or add new information just as fast as researchers report it. "They do have to enter it into the Baltimore system rather than in one of the nodes. The reason is that we have a very carefully integrated system, so if one editor enters information, it may have consequences for several other editors. And the system itself takes care of that," Dr. Pearson says.

The GDB was established by Dr. Frank Ruddle at Yale University in New Haven, Connecticut, in 1974 to keep track of genetics references in the literature. "At that time human gene mapping activities were just beginning. International conferences on gene mapping began to appear, and attendees started using that data base very informally just to store information," Dr. Pearson notes.

In 1985 more funding was needed to continue the work. The Howard Hughes Medical Institute agreed to support the project until 1990 and named it the Human Gene Mapping Library (HGML). "But it became obvious that researchers' needs were growing, and a service was needed to fill those needs. The HGML wasn't enough," Dr. Pearson says. So in 1990 the program was transferred to Johns Hopkins University, where it incorporated "essentially everything that was in the HGML" plus other information and was renamed the Genome Data Base. Currently the GDB staff numbers about 20 in Baltimore in addition to the editors around the world, he says.

To access the data base, researchers need only a computer with a modem. They first call the GDB staff in Baltimore to register and to give information on their local facilities and network support. Then they receive a log-on code and a user manual "and can get right down to it," Dr. Pearson says.

The system is designed to search on names of specific genes, or it can search for everything within a certain region of the map, such as all the genes within a given area of a chromosome. It also can search on polymorphisms and on names of cloned pieces of DNA. Within OMIM the data are organized according to mode of inheritance (autosomal dominant, autosomal recessive, or sex-linked) and can be searched using the names of genetic disorders or keywords describing disease characteristics.

When a user logs on, the system identifies him or her and as part of the output function can send the user information via EMAIL, an electronic transfer service. At present there is no facility for providing users with hard copy printouts, but depending on their own software capabilities, users often can obtain their own printouts by storing data displayed on their computer screens and then printing it out on their own printers.

There is no charge for using the GDB other than the cost of the phone call to access the system.

For more detailed information on the Genome Data Base, contact:
Genome Data Base
William H. Welch Medical Library
1830 East Monument Street
Baltimore, MD 21205
Telephone: (301) 955-9705

NIH
Research & Technology
Federal laboratory resource
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Imaging and Computer Vision Center

Researchers who study neurobiology can greatly benefit from new technology being developed at the Imaging and Computer Vision Center (ICVC) at Drexel University in Philadelphia, Pennsylvania, which allows better computerized analysis of autoradiographic images and thus enhances the understanding of neural activity and mechanisms.

This improved computer technology for image analysis permits researchers to map neurotransmitters and receptors more precisely; to determine metabolic rates in minute subregions of the brain; and to identify binding sites of various drugs, as well as potential ways to block the uptake of those drugs, according to Dr. Oleh Tretiak, principal investigator at the ICVC and professor of electrical and computer engineering at Drexel.

The ICVC was established 12 years ago within the university's department of electrical and computer engineering; it was then known as the Center for Image Processing and Pattern Recognition. Research at the ICVC is supported by the Biomedical Research Technology Program of the National Center for Research Resources, the National Cancer Institute, and the National Science Foundation.

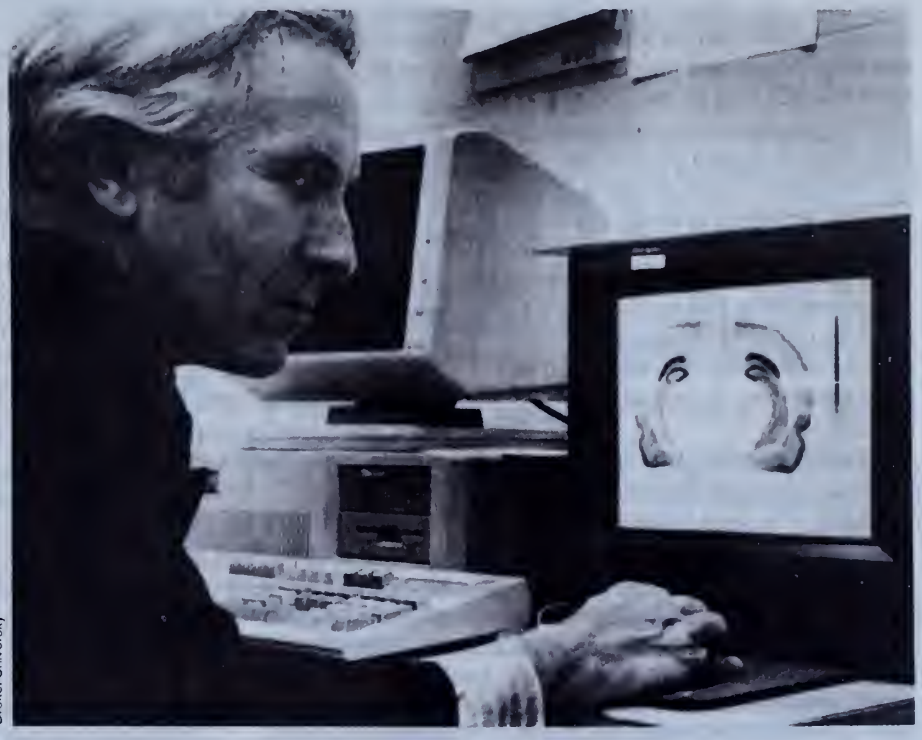
The ICVC is unique in that it is devoted to computerized analysis of autoradiographic images. "Many people work on image formation, but our thrust is on techniques of analysis and computer vision. We're engineers and computer scientists; other centers more typically employ physicists and biologists. Of course, we collaborate extensively with neuroscientific experts," Dr. Tretiak notes.

Dr. Tretiak defines autoradiography as the process of making visual images from the distribution of radioactive material imbedded in a substance or object. Investigators who use ICVC services or software typically work with samples from the central nervous systems of experimental animals. "If one wants to study a chemical that reacts specifically with a substance in the brain, the chemical is provided with a radioactive label and administered to the animal. After the reaction has taken place, the animal is sacrificed, and the brain is sliced into sections. The tissue sections are placed against x-ray films, which show contact prints of the location of the radioactive material. These are autoradiograms.

"Autoradiography is an exquisitely sensitive technique that can record the disintegration of individual atoms and molecules, so you can have minute traces of a certain chemical but still find out exactly where it goes," he explains.

Dr. Tretiak and his associates at the ICVC have developed computer software that processes an autoradiogram together with an image of the tissue section itself to determine the absolute concentration values of the radioactive material. The two images—one histologic and one autoradiographic—are collated by the computer. The investigator can then indicate on the computer screen which particular area on the histologic image he wants to study. The computer evaluates the corresponding area on the autoradiogram and measures exactly how much radioactivity there is in that area, Dr. Tretiak says.

The ICVC computer software allows collation of the two images by calibrating the film, correcting shading, automatically aligning the two images, and doing digital subtraction.



Drexel University

Dr. Oleh Tretiak is evaluating a computer display of an autoradiogram illustrating a metabolic study of a rat brain. Dr. Tretiak and his colleagues have developed computer software that processes an autoradiogram together with an image of the tissue section itself.

The program runs under the Xenix operating system and has a menu-driven user interface.

A newly developed version of the software for use with the Macintosh computer is currently being tested by investigators around the country, although it has not yet been officially released. "We are now working the 'bugs' out," Dr. Tretiak says. This software utilizes an on-screen palette and other Macintosh graphics features that are simpler for users. It allows the contours of the region of interest to be copied and moved, so they don't have to be redrawn when multiple sections are being analyzed. It also allows concurrent use of other Macintosh applications, so a high-resolution image can be copied to graphics or text documents and numerical data can be transferred to word-processing or spreadsheet documents.

"The most practical service we offer now is supplying software," Dr. Tretiak says. "We used to have researchers come to our laboratory to use our system. But since we have developed a microcomputer system and it has a pretty reasonable cost, researchers get software and equipment from us and do the work themselves. The software generally costs about $800, and the equipment is approximately $12,000, although these prices vary every year. Most researchers can afford that, and they'd rather have the whole setup in their own laboratory so they can use it at their convenience," he notes.

In addition to supplying software and hardware, the ICVC advises researchers on experimental design, analysis techniques, and suitable equipment to use in experiments involving image analysis. It also has training programs for investigators and offers seminars and short courses on image analysis.

Approximately 75 laboratories worldwide use ICVC services.

"Another computerized image technique that is very popular among neuroscientists today involves neuroreceptors and neurotransmitters," Dr. Tretiak says. "Brain cells communicate by means of chemical substances, not electrical impulses. Cells that are right next to each other ignore each other's chemical signals unless they have specific receptors for those chemicals. That's how the brain can do sophisticated processing; cells may be next to each other but are still independent.

"Use of our equipment for study of receptors is very important in the development of drugs that affect the brain," Dr. Tretiak says. One researcher who uses ICVC software has developed radiolabeled ligands for cocaine. He hopes to map cocaine receptors in the brain and perhaps discover a way to block these receptors to negate the effects of the drug.

Other investigators use ICVC software to study the causes, neurochemistry, and potential treatments for neuropathologic conditions such as Parkinson's disease, Alzheimer's disease, epilepsy, ischemia, and drug addiction.

ICVC staff also is actively involved in research, Dr. Tretiak points out. "We are engineers. We are primarily oriented toward building things that will be useful," he says. To that end, he and his associates are developing an expert system that will take the place of experienced neuroanatomists who must examine the autoradiograms and brain sections "to identify what's what.

"Currently, even with the aid of a computer, we still need expert neuroscientists to indicate where to do our measurements. So we are developing technology that will allow data about the appearance and location of brain sections to be stored in the computer. It would then use this knowledge to look at a section and identify various structures," he says.

"This would have several advantages other than freeing up the neuroscientist. Now, different people in different laboratories are doing these measurements, and we are not sure whether the criteria used to define a region to be measured are the same in all laboratories. That limits the degree to which we can compare the data," Dr. Tretiak explains.

"Also, because these measurements are so tedious to do by hand, there is a limited amount of data being measured now. That limits the sensitivity of the technique.

"With machine-aided delineation, we hope to have greater reproducibility of measurements from one time to another and from one laboratory to another. It also would become practical to do larger experiments, which would make the technique more sensitive. And, with the data in computer-readable form, we could develop a network to facilitate interchanging data between laboratories, and even collaborating on experiments in different locations," he predicts.

For more information about the ICVC contact:
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NASA Tech Brief
National Aeronautics and Space Administration

Computation of Facilitated Transport of O_2 in Hemoglobin

Unsteady transport is simulated with more-realistic mathematical models of dissociation.

A report describes computations of the unsteady facilitated transport of oxygen through a liquid membrane of hemoglobin. As used here, "facilitated transport" means the diffusion of a permeant through a membrane in which that diffusion is enhanced by a reversible chemical reaction between the permeant and the membrane. In this case, there are reversible reactions between the hemoglobin and oxygen.

The differential equations that describe unsteady transport of oxygen (including the reactions of higher order) in one dimension across a solution containing hemoglobin are presented. First, the steady state is considered, and the equations are linearized into a coupled set of ordinary differential equations. These equations are put in a matrix form that highlights the disparate time scales related to rates of transport and of reaction of the various chemical species. This linearized form is used to develop an explicit formula for the size of the boundary-layer region. The facilitated-transport problem is shown to be "stiff" in the sense that the solution includes eigenmodes of disparate spatial scales.

The full nonlinear time-dependent equations are solved by the method of time linearization, using an explicit numerical-integration algorithm with direct block tridiagonal solvers. The method of time linearization involves the expansion of the nonlinear term in a Taylor series about the solution at a previous time step. The solutions of the full nonlinear equations are presented and compared with results published previously. The most important results of the analysis are the following:

- Reaction models of higher order, which match oxygen-dissociation-curve data better than do models of lower order, yield better agreement between theory and experiments in vitro.
- The steady-state oxygen flux through a membrane is independent of the initial conditions.
- In the computation, the sigmoid oxygen-dissociation curve (the ratio of the concentration of oxyhemoglobin to the total concentration of hemoglobin) causes almost 100 percent oxygen saturation of the high-pressure side of the membrane and increases the thickness of the boundary layer on the low-pressure side. This latter effect relaxes the stringent grid-resolution problems when numerical methods are used.

This work was done by Sanford Davis of **Ames Research Center.** *To obtain a copy of the report, "Computation of the Unsteady Facilitated Transport of Ozygen in Hemoglobin Solution," ARC-12417/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Natural Resources Technology & Engineering

0827 Abandoned Mine Lands Program TN#1 Subsidence Abatement Investigation Laboratory (SAIL)

Other Items of Interest

0803 Highly Accurate Sensor for Soils

New Technology from the U.S. Bureau of Mines

U.S. Department of the Interior

Abandoned Mine Lands Program TN#1 Subsidence Abatement Investigation Laboratory (SAIL)

Objective

Provide a full-scale test facility where the effectiveness of all types of subsidence abatement techniques can be evaluated under controlled conditions.

Background

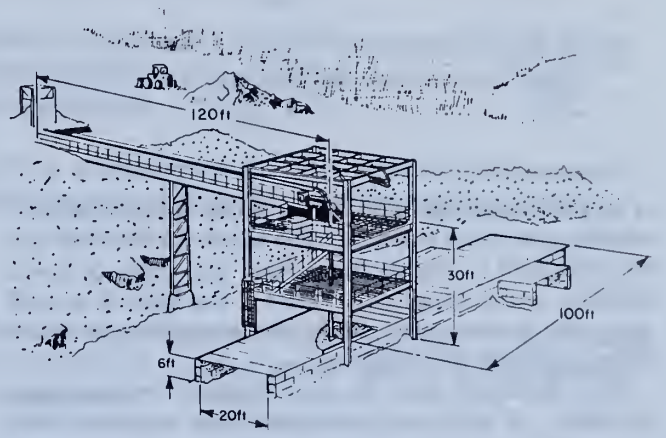
Subsidence is ground movement resulting from the collapse of overlying strata into a mine void because of failure of the mine roof, mine floor, or support pillars. The failure may propagate to the surface and be expressed as a depression, cracks, or a sinkhole. The surface expression of such features may be delayed until long after mining has been completed.

Subsidence has the potential to affect more land area than any other type of abandoned mine land problem. Subsidence also causes direct damage to real property, with significant financial loss and more importantly, presents a danger to public health, safety, and general welfare. Subsidence-related problems are considered to be one of the most important abandoned mine land issues.

Backfilling of mine voids is the most common stabilization method used to abate subsidence and protect surface structures. Backfilling or placement of material is performed by hydraulic flushing or pneumatic stowing, using either in-mine or remote methods. The majority of the past subsidence abatement projects has been performed using remote methods from single or multiple boreholes. Other subsidence abatement techniques are available. For example, various point support methods are used to protect small areas of the land surface and surface structures, without completely filling the mine void. These may be more appropriate under different conditions. Little documented information is available concerning the capability of the various backfilling methods for completely filling a mine void or providing long-term structural strength. Therefore, the Bureau of Mines developed a laboratory for controlled evaluation of backfilling technologies.

Approach

The SAIL design is quite flexible, and can be most simply described as a surface structure that simulates a borehole drilled into a mine void. The configuration illustrated in the figure was used to simulate remote backfilling in a typical coal mine. However, with slight modifications the laboratory may be configured to a number of different conditions, i.e., the backfilling of open stopes, tunneling and backfilling in a flooded mine. General specifications of the SAIL are listed in the table.



Artist rendering of the Bureau's subsidence abatement investigations laboratory (SAIL) configured to simulate remote backfilling in a typical coal mine.

Capability

The laboratory structure consists of a 3 story, 30-ft by 30-ft steel tower with two elevated working platforms. The upper platform is 36 ft above the simulated mine floor. Access to the working platforms is by a catwalk on the elevated conveyor bridge. The conveyor bridge provides the supporting structure for a 24-in conveyor belt, a 6-in conveying pipeline and utility conduits. The combination of the conveyor belt and the conveying pipeline permits the delivery of material to the top of the borehole in bulkform, as a slurry or by pneumatic transport.

The tower is a framework for the borehole and its supporting equipment. However, the design loading of the tower is such that, if needed, additional equipment required for a specific series of tests, may be mounted on either of the work platforms. The borehole is sized to provide an 8-in-diameter opening. Borehole simulations

TABLE 1 - Specifications

Tower height	
Total	45 ft
Upper platform	36 ft
Lower platform	15 ft
Tower width	30 ft by 30 ft
Support Equipment	
Belt conveyor	24 inch - 150 ton/h capacity
Transport pipe	6 inch diameter
Water supply line	1000 gal - pressurized 1-1/2 inch
Air supply	3 inch supply line to borehole from portable compressor (125 psi max)
Borehole size	8 in diameter standard (up to 10 inches)
Hoist capacity	1-1/2 ton
Simulated mine	
Height	10 ft maximum
Length	150 ft maximum
Width	20 ft maximum

of up to 10-in in diameter can be accommodated without modification to the structure. The simulated borehole can be configured to extend from either the upper or lower platform to the mine roof. A 1-1/2 ton hoist is located above the borehole for use in lowering casing or backfilling tools into the borehole.

The simulated mine is also designed for maximum flexibility. It has been constructed from concrete block walls with steel bridge planks serving as the mine roof. The concrete blocks used for the walls are interlocking "Jumbo Blocks" usually used for retaining walls. Each block measures 2-ft high by 2-ft wide by 6-ft long, and weighs 1-1/2 ton. This size allows the blocks to be set in place on a level fill without a permanent foundation. Thus, the configuration of the mine is not restricted by a foundation and can be rearranged as needed for a specific test. An intersection can be established beneath the tower, since it is designed with a wide enough base to allow 20 ft wide openings in each of four directions. The roof of the simulated mine is removable, permitting direct observation of the fill placement, in-situ testing of the fill and excavation of the fill material. When needed, the roof can be secured to a series of studs which are embedded into the upper row of blocks.

Research Accomplishments

To date, a prototype "Air-Jet" style injector and four collapsible elbow/nozzle combinations for use with conventional stowing equipment have been evaluated at the laboratory. The tests were conducted to demonstrate the capability of pneumatic stowing as a subsidence abatement method and to measure the performance of the various techniques. In comparison to the plain pipe elbow currently used, all of the devices tested significantly improved the state-of-the-art by providing a greater trajectory and void filling capability. Based on this evaluation, it has been technically proven that pneumatic stowing is a viable means for backfilling abandoned mine openings, especially in areas where water is unavailable. Pneumatic stowing techniques may be used to place fill in over 200 linear ft of limited-height mine openings from a single borehole by directing the discharge down the center of the mine void. The fill is placed in a medium-dense condition and can achieve roof contact for more than 100 ft of the overall length.

For More Information

Requests for more information about the capability and technical specifications of the Bureau's SAIL and about the current testing program should be directed to: Jeffrey S. Walker, Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236, (412) 892-6545.

Physical Sciences

0828 Eyes Protected Against Laser Sources (Licensing Opportunity)

0829 Navy Invents Protective Communications Helmet (Licensing Opportunity)

Testing & Instrumentation

0830 GC/MS Gas Separator Operates at Lower Temperatures—Less power is consumed, and the catalytic hydrogenation of compounds being analyzed should be diminished.

0831 Measuring Flux Density of Monatomic Oxygen—Two probes measure heat of recombination on a catalytic surface. (Licensing Opportunity)

Other Items of Interest

0782 Compact X-Ray and Extreme-Ultraviolet Monochromator—This low-cost monochromator can operate at selected wavelengths in a wide spectral range. (Licensing Opportunity)

0804 Sensing Chemicals

0815 The Monomer of Your Choice Can Now be Modified—Enzymes Add Carbohydrates for Synthesis of Biocompatible Polymers (Licensing Opportunity)

Eyes Protected Against Laser Sources

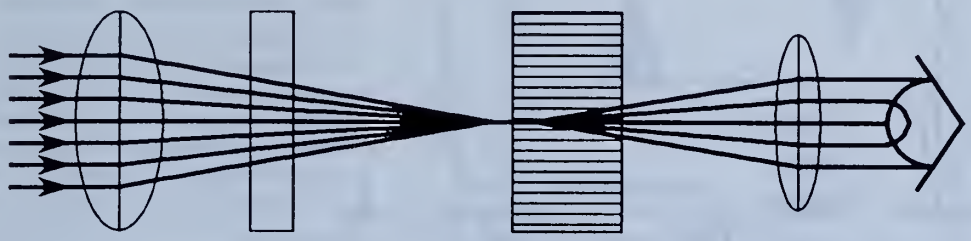


Figure 1. Nonlinear optical filter

The Naval Surface Warfare Center (NAVSWC) has found that nonlinear optical materials provide protection for eyes and light-sensitive equipment from laser energy but do not interrupt normal light energy to these receptors (Figure 1). The materials permit unimpeded passage of the normal intensity spectrum, while either absorbing high-intensity sources or changing them into a harmonic outside of the desired spectrum where they are subsequently filtered. Optical elements focus the waist of the beam within a nonlinear frequency-doubling optical fiber element. The nonlinear elements produce a harmonic outside the visible spectrum and absorb the laser energy. Response time is in nanoseconds. In contrast to this approach for laser protection, other types of filters exclude a band of the spectrum being received, and shutters completely close off the input signal.

The invention may use more than one filter and is adaptable with lenses to construct a telescope, binoculars, or can be incorporated into such equipment as image intensifiers. A preferred form uses either fiberlike tubes containing a nonlinear optical fluid or solid polymer fibers that absorb high-intensity laser energy while passing the low intensity spectrum. This device may employ an array of these optic fibers, which facilitate matching with fiber array image intensifiers.

The features of the invention include: completely passive operation, no power sources required; eye-equipment protection against incident laser radiation having changeable frequencies (frequency agile lasers); protection against laser energy without blocking normal viewing modes; safe user viewing of scenes while being illuminated with hostile laser energy.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 160101/TN

Navy Invents Protective Communications Helmet

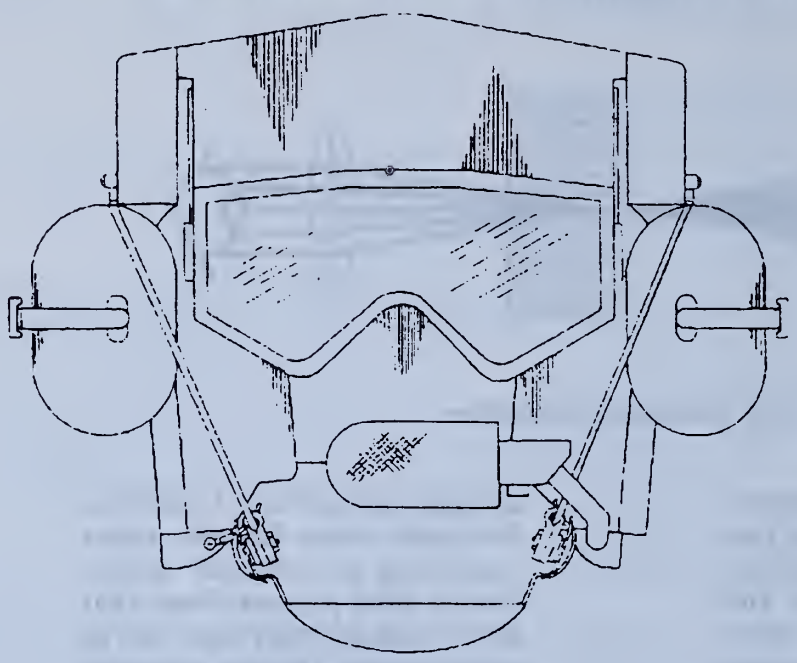


Figure 3. Protective communications helmet

The Naval Ocean Systems Center (NOSC), San Diego, California, has invented a protective communications helmet (Figure 3), combining aural, visual, flying object, and bump-guard, protective features with electronic communications. The helmet includes a multiple section shell comprised of a central shell to which lateral electronics compartments are removably attached. It has a sturdy lightweight frame for mounting various noninterfering equipment and has a simple size adjustment for universal fit.

The weight and surface area are distributed physiologically and functionally over the head and neck in a manner tolerable for long periods of time. The central shell and lateral electronics enclosures are designed by the use of planar approximations thus permitting the center of gravity of the helmet to be positioned as low as possible and as close to the head pivot point as is possible, which will reduce moments of inertia.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 160105/TN

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

GC/MS Gas Separator Operates at Lower Temperatures

Less power is consumed, and the catalytic hydrogenation of compounds being analyzed should be diminished.

Experiments have shown that a palladium/silver tube used to separate the hydrogen carrier gas from the gases being analyzed in a gas-chromatography/mass-spectrometry (GC/MS) system functions satisfactorily at temperatures as low as 70 to 100 °C. Heretofore, it was believed necessary to maintain operating temperatures between 200 and 250 °C to obtain adequate separation.

Figure 1 illustrates the experimental apparatus and the principle of operation. The 75-percent palladium/25-percent silver separator tube is sealed inside a stainless-steel outer tube. The hydrogen carrier gas (and any entrained gas to be analyzed) flows along the Pd/Ag tube toward the ion source of a mass spectrometer. The hydrogen diffuses through the wall of the Pd/Ag tube to the annulus between the inner and outer tubes. Oxygen flowing in the annulus combines with and sweeps away the hydrogen. Thus, the gas emerging from the output end of the tube contains a much lower concentration of hydrogen and, consequently, a much higher concentration of the gases to be analyzed. The experimental data indicate that the separation efficiency — that is, the fraction of entering hydrogen removed through the wall of the Pd/Ag tube — increases with temperature, as expected. The data also indicate that nearly complete separation is achieved at temperatures below 100 °C (see Figure 2).

At the conventional higher operating temperatures, the Pd/Ag alloy undesirably catalyzes the modification and hydrogenation of some of the gases being analyzed — particularly dienes and nitriles. At the proposed lower operating temperatures of 70 to 100 °C, it is expected that these catalytic effects will be suppressed. Operation at lower temperatures would also require less heater power. Furthermore, because the separation efficiency is still high even at the lower temperatures, the gas load on the vacuum pump of the mass spectrometer can be kept low, permitting the use of a smaller pump. These features are expected to facilitate the development of a relatively small, lightweight, portable GC/MS system for such uses as measuring the concentrations of pollutants in the field.

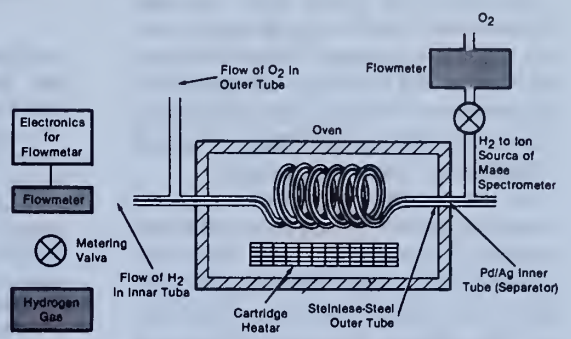


Figure 1. This **Experimental Apparatus** was used to determine the separation efficiency of the Pd/Ag tube as a function of temperature.

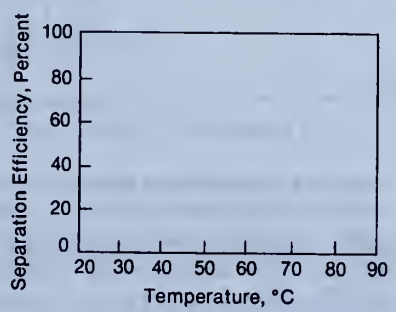


Figure 2. The **Separation Efficiency** approaches 100 percent at temperatures well below the conventional minimum operating temperature of 200 °C. Beyond the precision of this plot, the data indicate a separation efficiency of 99.98 percent at 78 °C.

This work was done by Mahadeva P. Sinha of Caltech and George Gutnikov of California State Polytechnic University Pomona for **NASA's Jet Propulsion Laboratory.** *NPO-17930/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Measuring Flux Density of Monatomic Oxygen

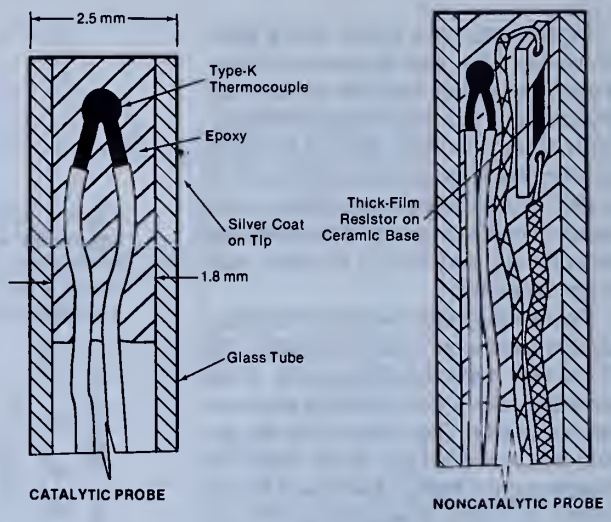
Two probes measure heat of recombination on a catalytic surface.

An improved version of the catalytic-probe technique yields more accurate measurements of the flux density of neutral, monatomic oxygen. The principal application of this technique will likely be in experiments in which oxygen plasmas are used to examine the degradation of various materials by monatomic oxygen.

In the catalytic-probe technique, one measures the flux density of oxygen atoms indirectly by measuring some of the heat generated by the recombination of oxygen atoms into oxygen molecules on a catalytic probe surface. The improved version of the technique involves two similar probes, one of which is catalytic, the other of which is not. Both probes (see figure) include glass tubes that contain type-K thermocouples sealed in epoxy near the measuring tips. A thick-film heating resistor on a ceramic base is also sealed into the epoxy near the thermocouple in the noncatalytic probe. The other probe does not contain a resistor, but its outer surface is coated with silver, which quickly oxidizes and becomes a catalyst for the recombination of monatomic oxygen. The emissivity of the silver oxide is 0.85 — the same as that of the glass.

The probes are mounted near each other in the plasma chamber and operated simultaneously so that both sample nearly the identical atmosphere and its atomic-oxygen content. (One of the weaknesses of prior versions of the technique is that they involved single probes and sequential measurements in which identical conditions could not be assured.) The temperature measured by the thermocouple in the catalytic probe includes the effect of heat released by recombination of oxygen. The electrical power delivered to the resistor in the noncatalytic probe is measured and automatically adjusted by control circuitry that attempts to keep the temperature in the noncatalytic probe the same as that in the catalytic probe. Under this condition, the electrical heating power is nearly proportional to the rate of recombination and, therefore, to the flux density of monatomic oxygen. The noncatalytic probe can also be operated without heating to measure the temperature of the probed atmosphere.

The total flux of oxygen atoms that strike the probe is computed from the known energy released in each recombination (5.2 eV) and the empirically determined proportionality between the heating power and the increase in temperature above ambient. The flux density is then found by dividing the total flux by the area of the catalytic surface. If the probed atmosphere is thermal, then the number density of oxygen atoms can be computed from the flux density and the temperature.



The **Catalytic Probe and the Noncatalytic Probe** measure the rate of heating caused by the recombination of monatomic oxygen on the catalytic surface. The flux density of monatomic oxygen is proportional to this rate of heating.

This work was done by M.R. Carruth, Jr., R.F. DeHaye, J.K. Norwood, and A.F. Whitaker of **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28446/TN

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